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LIMITING ROOT ZONE LEACHING TO REDUCE GROUNDWATER CONTAMINATION IN SANDY SOILS

by

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ABSTRACT

LIMITING ROOT ZONE LEACHING TO REDUCE GROUNDWATER CONTAMINATION IN SANDY SOILS

This study monitored the effect of limiting agricultural leaching for the purpose of reducing this source of groundwater contamination. Five field plots in soils of a Hanford series were covered with plastic sheets and drip irrigated to field capacity. A $CaCl_2$ tracer was applied to the surface of each plot at the beginning of the study. Movement of the tracer was monitored through a 3-m profile with replicated leaching fraction treatments of 50% and 10% ETo. In the 50% leaching plots the tracer had moved through the sample depth after 4 months. In the 10% leaching plots the tracer remained within the sample depth at the completion of the 6-month irrigation season. Limiting the amount of leaching reduced the seasonal movement of a water soluble tracer, allowing it to remain in the biologically active upper soil layer for a longer period of time.

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INTRODUCTION

California's ground water resource, which accounts for 39% of the water used in the state, is particularly susceptible to contamination by toxic chemicals. An estimated 9.1×10^5 hectare-meters of water from agricultural, municipal, and industrial use seeps back into ground water basins annually (DWR, 1987). For centuries, it was believed that the soil layer above would filter out contaminants before they could reach the aquifer below, resulting in a relatively pure, contamination-free source of water. In fact many soils have proved to be poor filters of the fertilizers, pesticides, and industrial byproducts which have been applied, stored, or disposed of and are being detected in water supplies throughout California.

This study was designed to monitor the effect of limiting agricultural leaching for the purpose of reducing groundwater contamination. The research was conducted in field 15 of the California State University, Fresno farm laboratory. The soil of this field is classified as a Hanford series (coarse-loamy, mixed, thermic Typic Xerorthents) and consists of well-drained, fertile, moderately coarse-textured soils formed in recent granitic alluvium (USDA, 1971).

The pesticides and fertilizers used on cultivated soils move as soluble constituents of the water, which leaches below the root zone, to recharge ground water basins. The rate of ground water contamination therefore depends upon the solubility of the applied compounds, the amount of applied water in excess of evapotranspiration, and the hydraulic conductivity of the soil profile. The incidence of groundwater contamination from applied agricultural chemicals and nitrates in discrete areas of the eastern San Joaquin Valley may often be due to a combination of these factors that result in rapid leaching of the root zone with large volumes of irrigation water.

The Environmental Hazards Assessment Program (EHAP) of the California Department of Food and Agriculture (CDFA 1985) initiated a project to collect information on contamination of ground water from non-point sources. The California Department of Food and Agriculture's EHAP 1990 Update includes data from 29,923 analyses taken from 2,761 wells in 52 counties (CDFA 1990). Pesticide residues were detected and confirmed in 163 wells (6%) in 15 counties. Of the 192 pesticide active ingredients and breakdown products analyzed for, 14 were present in ground water. The CDFA has determined that 6 of the 14 contaminants present in ground water were the result of agricultural use.

Theoretically the contamination of groundwater with applied agricultural chemicals and fertilizers can be delayed and substantially reduced by decreasing the amount of leaching water that escapes well below the root zone. By reducing the rate at which contaminants travel through the soil toward the aquifer there would be more potential for residues to dissipate through microbial decomposition, chemical degradation, or volatilization as these materials would remain in the biologically active upper soil layer for a longer period of time.

After 4 years of below average rainfall in California the importance of water conservation management in agriculture is well established. An additional advantage of crop water conservation management may be the protection of our ground water resources from contamination.

A chloride tracer was used in this study to model pesticide movement. Pesticides generally are not as soluble as chloride and may react differently within the soil. This study therefore models only the soluble fraction of a pesticide or its soluble constituents as it biodegrades.

The purpose of this study was to monitor the effect of two leaching fractions (50% Eto [evapotranspiration]; and 10% Eto; applied every 3 days), on the downward movement of a chloride tracer throughout a growing season. An additional plot simulated a flood irrigation and monitored the seasonal tracer movement after one irrigation of 28% Eto.

LITERATURE REVIEW

Water Movement Through Sandy Soils

The rate of water movement through a soil profile toward the ground water depends directly upon the hydraulic conductivity of the soil and the relative amounts of saturated and unsaturated flow below the root zone. In the saturated mode, sandy soils have high vertical flow rates ideal for recharging ground water basins. The amount of leaching in coarse-textured soils will often be greater than with other soils because it is more difficult to irrigate these soils efficiently.

In a saturated soil of stable structure the hydraulic conductivity is characteristically constant. Its order of magnitude is approximately 10^{-2} to 10^{-3} cm s^{-1} in a sandy soil and 10^{-4} to 10^{-7} cm s^{-1} in a clayey soil (Hillel, 1980). Sandy soils by definition are comprised of a large percentage of coarse soil particles ranging in size from 2 to 0.05 mm (USDA-SCS, 1975).

The hydraulic conductivity of soils and the rate of water movement is affected primarily by the internal characteristics of the soil. Total porosity of the soil affects conductivity relative primarily to the size of the conducting pores. Sandy soils have less total porosity than clay soils yet have higher conductivity values due to the relative size of the conducting pores. Cracks, worm holes, and decayed root channels also affect water flow depending on the direction and condition of the flow process (Hillel, 1980).

Five zones were defined by Bodman and Colman (1944) in a uniform soil into which water was entering at the top to a wetting zone at the lower end. The zones in series were described as: (a) a saturation zone at the surface which extended to 1.5 cm in their soil; (b) a transition zone, a rapid decrease of water content extending to a depth of about 5 cm from the surface; (c) the main transmission zone, a region in which only small changes in water content occurred; (d) a wetting zone, a region of fairly rapid change in water content; and (e) the wetting front, a region of very steep gradient in water content which represents the visible limit of water penetration. The movement of water in soils is due primarily to the rate at which water is supplied to the transmission zone. The matrix potential of this zone is close to zero and the pore space is approximately 80% saturated so that water movement within is caused primarily by gravity (Marshall 1959; Kramer 1983).

The theory of liquid water movement in soils is based on Darcy's Law, which states that the flow of a liquid through a porous medium is in the direction of, and at a rate proportional to, the driving force (i.e., the hydraulic gradient) acting on the liquid and also in proportion to the property of the conducting medium to transmit the liquid (Darcy 1856).

Movement of Solutes in Soil

Water present in the soil in its liquid phase is never chemically pure. As water moves through the soil profile it carries its solute load in its convective stream, leaving some of it behind to the extent that the component salts are adsorbed, taken up by plants, or precipitated whenever their concentration exceeds their solubility (Hillel, 1980).

Research of leaching characteristics and miscible displacement has been performed primarily with containerized media in an attempt to develop descriptive models (Biggar and Nielsen, 1962, 1967; Kerr and Hanan, 1985). Many of these studies have emphasized the interactions of the physical and chemical processes that govern the transient nature of soil solutes.

It has been reported that the proportion of large pores in a peat-perlite-glass bead mix affects the amount of water required to leach out salts (Kerr and Hannan, 1985). Salt removal from mixtures with low percolation rates was much more efficient than from those mixtures with higher percolation rates. Salt removal efficiency in mixtures with low percolation rates is attributed to a piston effect in small capillaries, and the fact that slow water movement through the capillary system allows more intimate mixing and more time for ions to diffuse into the mainstreams (Biggar and Nielsen 1967; Hanan 1981).

Several theoretical models were examined by Nielsen and Biggar (1961, 1962, 1963) as to their usefulness in describing miscible displacement in porous materials. It was concluded that the analytical description of mixing has been made in the range of velocities greater than those found in most soils, and even for these media the dispersion coefficient to pore distribution is not well defined.

The miscible displacement theory holds that mixing between soil and leaching solutions can be attributed to: (a) variations in pore water velocities (hydrodynamic dispersion), which arise from distribution of pore sizes and shapes; (b) diffusion of ions from regions of high to low concentration; (c) ion adsorption and exchange reactions; (d) differing densities and viscosities of the soil and leaching solutions (Kerr and Hanan, 1985).

Chemical Tracers

The ions usually considered most useful and nearly ideal as indicators of water movement are Cl^- and NO_3^-. In most soils, they appear to move at an equal rate with each other and with the water (Fulcher and Tyner,1959; Cassel 1971).

A thorough evaluation of chemical tracer movement in soils was examined by Kurtz and Melsted (1973). They concluded that the Cl^- ion may encounter negative or positive adsorption to a limited extent in some tropical soils.

In a field study by Biggar and Nielsen (1976) it was concluded that substantial errors can be made in estimating the flux or the amount of solute passing below the root zone of a crop by multiplying average values of the flux of water by average values of the concentration of the soil solution. They expect that point measurements of solution samples from suction probes and excavated soil samples would provide a good indication of relative changes in the amount of solute being transported but not quantitative estimates sufficiently precise to ascertain the amounts of fertilizers or other solutes leached beyond the recall of roots. It was suggested that only by a thorough analysis of the frequency distribution of such measurements would quantitative results be assured.

METHODS AND MATERIALS

Five circular plots, each 20 m in diameter, were located in field 15 of the CSUF farm-laboratory and are diagramed in Fig 1. This study area is mapped as Hanford sandy loam, 0 - 2% slopes. Results of particle size analysis confirmed that sand dominates the textural classifications throughout the 3-m profile of each plot. The soil of plot 3 has a slightly lower sand and a slightly higher clay percentage at the 0.5, 1.0 and 3-m depths relative to plots 1, 2, 4, and 5 (see Appendix Table 11).

The monitoring instruments were confined to a 10-m diameter circle in the center of each plot to allow a buffer zone between adjacent plots. The plot design is illustrated in Fig. 2. The monitoring instruments included tensiometers and ceramic tipped PVC pipe suction probes. Both devices were placed at 0.5-m increments to a maximum depth of 3 m. The tensiometer placements were replicated two times per plot while the suction probes were replicated three times. The monitoring instruments extended to the surface through the plastic and were sealed to prevent evaporation.

Each circle was covered with two plastic sheets and then protected with soil to minimize water loss due to transpiration and evaporation, and to reduce the effect of rainfall.

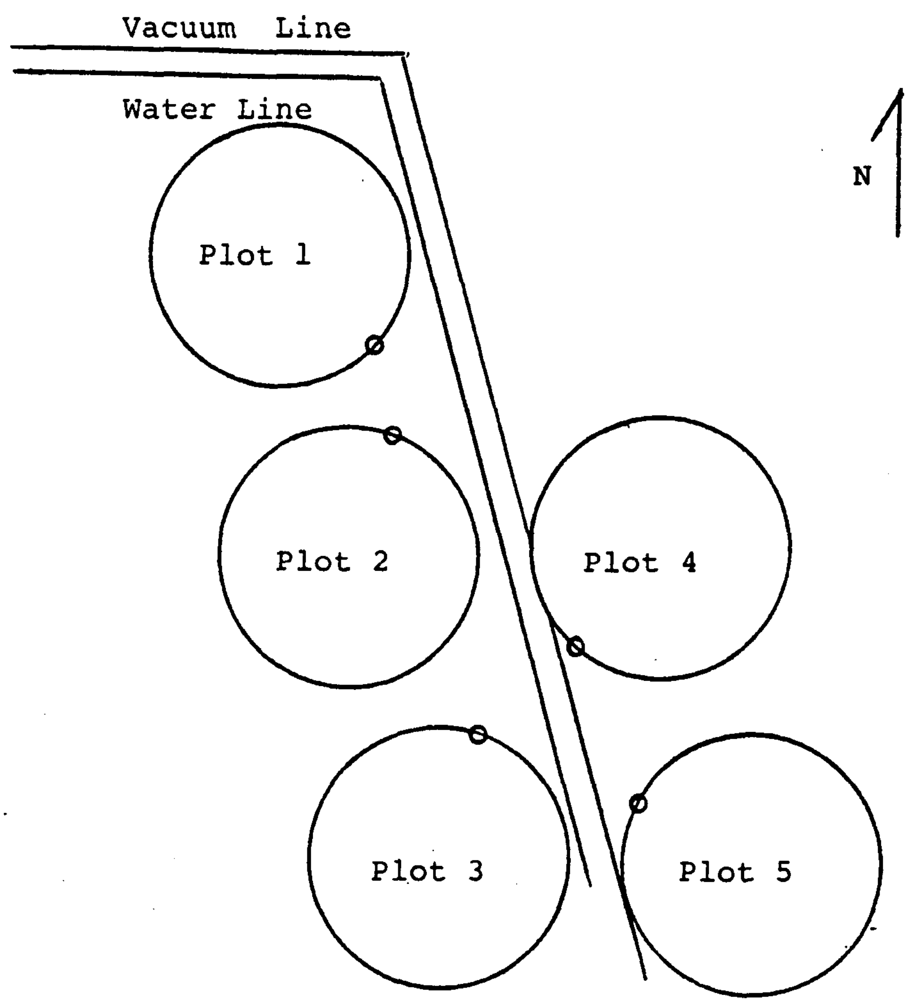
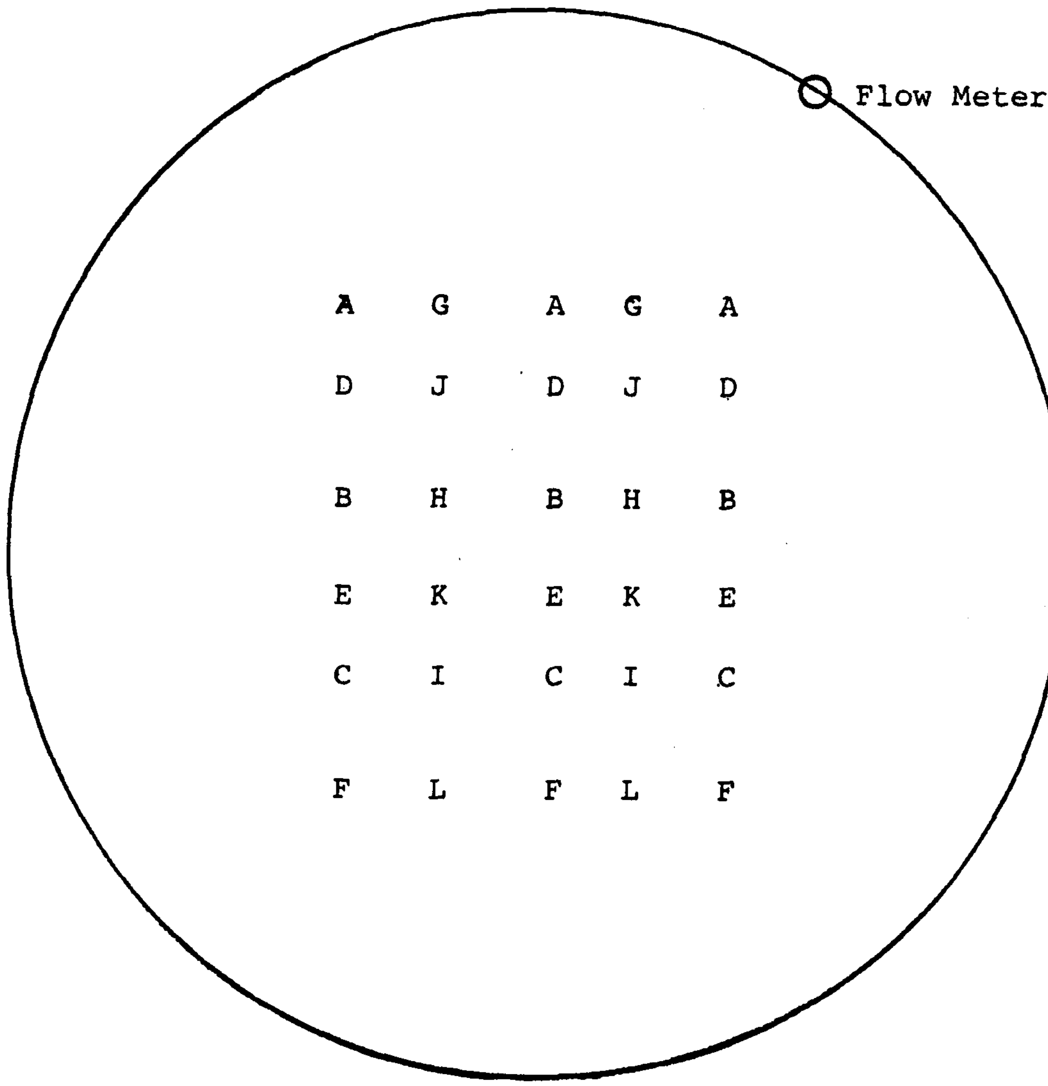


Fig. 1. Experimental area diagram



<u>Suction sampler depths</u>

A = 0.5 m
B = 1.0 m
C = 1.5 m
D = 2.0 m
E = 2.5 m
F = 3.0 m

<u>Tensiometer depths</u>

G = 0.5 m
H = 1.0 m
I = 1.5 m
J = 2.0 m
K = 2.5 m
L = 3.0 m

Fig. 2. Typical plot layout

The water source for this project was a well located in field 15 which was analyzed four times for Cl and consistently contained a level of 4 mg L^{-1}. Water was applied through Netafim RAM pressure compensating dripper lines. Emitters with discharge rates of 3.78 L per hour were spaced in a 1-m grid on the soil surface under the plastic. A programmable timer and electronic solenoids on each plot facilitated the irrigation schedules while in-line flow meters recorded the applied water to the gallon.

Prior to the application of the $CaCl_2$ tracer, each plot was irrigated to field capacity and the matrix potential was confirmed with weekly tensiometer readings. Background Cl levels were determined with soil core extractions and four vacuum soil water samples. A Cl tracer was then applied through the drip system to the surface of each plot at 3398 grams on 12 Dec. 1989.

Due to the absence of evaporation and transpiration only the leaching fraction treatment amounts were actually applied to the plots. To four of the plots, water was applied every 3 days for a 6-month simulated growing season beginning 8 Jan. 1990 and ending 9 July 1990. One plot was designed to simulate a flood preirrigation and received all applied water in one continuous irrigation. The water application amounts were calculated using the average historical ETo data for the CSUF CIMIS (California Irrigation Management System) weather station during the

Weekly direct measurements of the matrix potential for each plot was made with tensiometers. All measurements of the 60 tensiometers were recorded with an SMS Tensimeter. The Tensimeter employs a transducer attached to a needle which penetrates a septum stopper mounted on each tensiometer.

RESULTS AND DISCUSSION

Of the 2916 samples from the porous tipped suction probes, 141 (5%) of the samples yielded an insufficient quantity for analysis. Probes located at the 0.5-m depth were observed to be the source of over 50% of the insufficient sample yields. Possible explanations for this observation may be the probes spatial location relative to the wetted area of the surface emitters, or that the shallow probes were pulling air from the soil surface. Other missing data were the result of random vacuum leaks within the system.

Several chloride spikes were observed in the raw data which did not appear to be the result of the applied tracer pulse. These anomalies resulted when a high Cl concentration was recorded as a sole event, and could not be supported by proximate samples or with similar values at a replicated site. The seven outlying data points identified in Table 1 have not been included in the tabulated averages.

Two possible explanations for the Cl data spikes include evaporative concentration of the chloride due to vacuum leaks or contamination of an individual sample at the plot manifold with bird guano. Both of these scenarios were observed during the field operations.

Table 1. Dates and Locations of Anomalous Chloride Data

Date	Plot	Rep.	Depth
1/15	3	A	0.5 m
3/5	4	A	1.0 m
4/23	3	B	2.5 m
4/23	4	B	1.5 m
5/28	1	A	0.5 m
6/4	3	C	2.0 m
7/2	3	C	2.0 m

Note: Raw data listed in Appendix Tables 6-10.

Soil Matrix Potential

The replicated tensiometer readings (see Appendix Tables 12-14) have been averaged and a graphical description of the weekly soil matrix potential for each plot is presented in Figs. 3-7. The graphs illustrate the lack of moisture uniformity in the soil profile during the months of Nov. and Dec., prior to the application of the Cl tracer. Before the tracer application on 2 Jan., the entire 3-m profile was wetted to field capacity. The tensiometer readings used for graphing have not been corrected for depth, so that the soil profile depths can be easily distinguished. The uniform wetting of the profiles was designed to minimize tracer movement due to matrix potential differences.

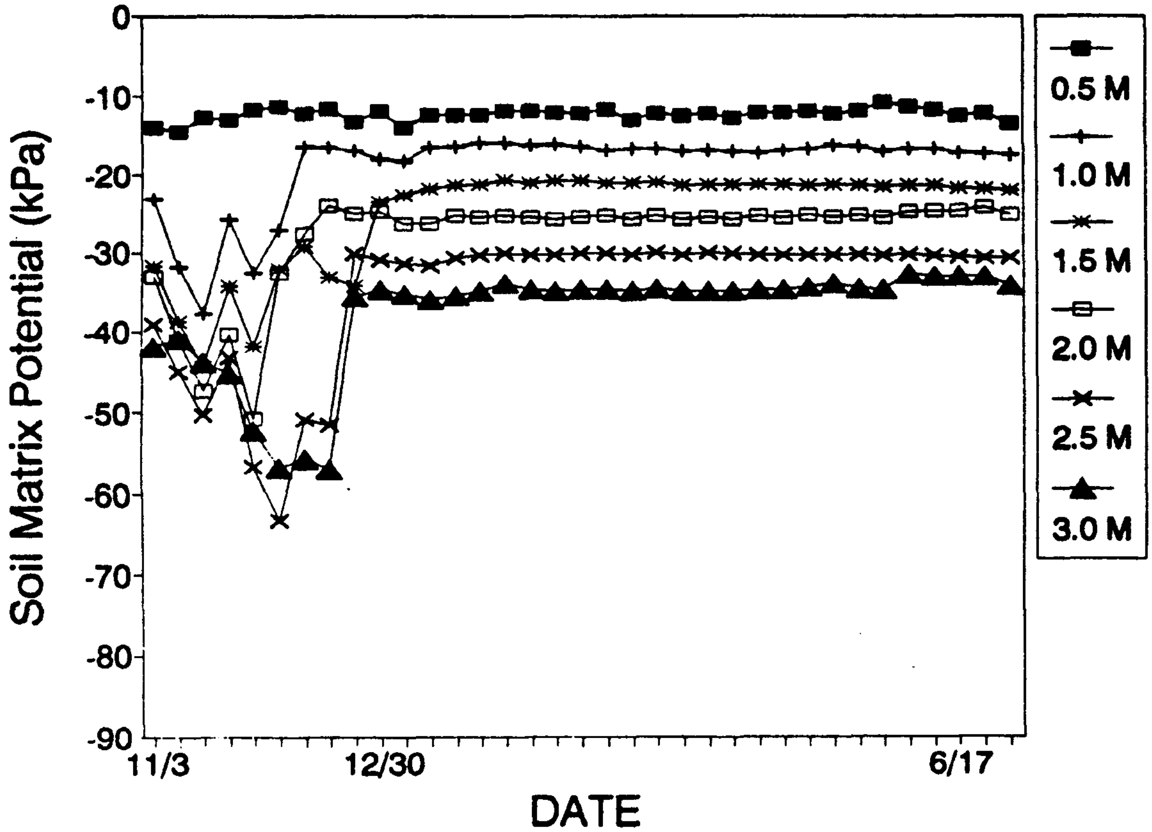


Fig. 3. Plot 1 Tensiometer Readings

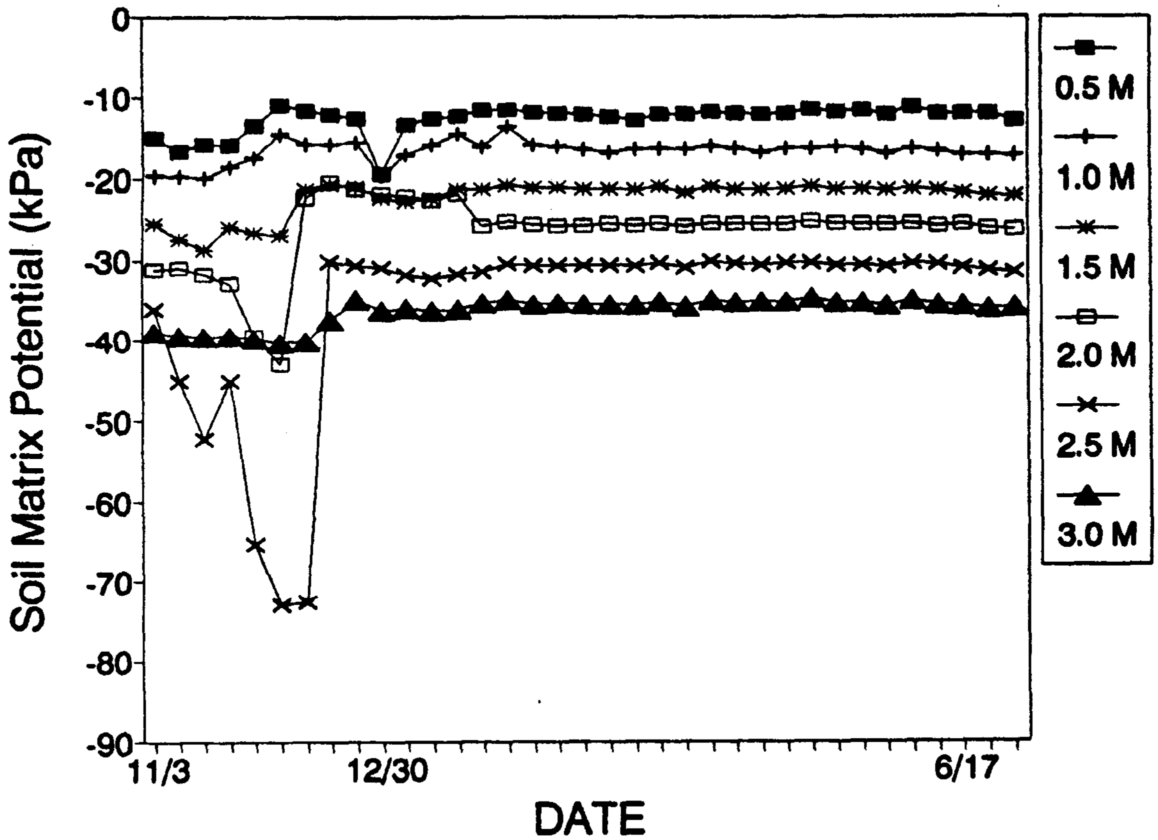


Fig. 4. Plot 2 Tensiometer Readings

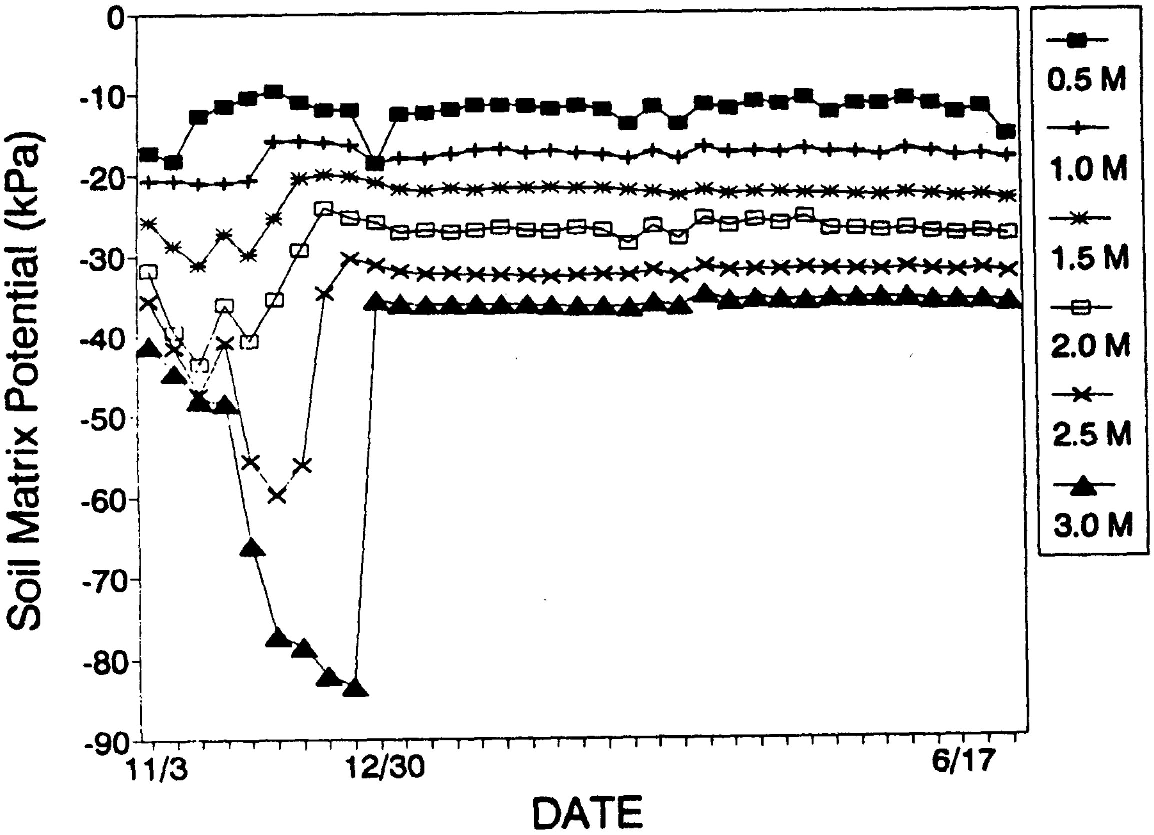


Fig. 5. Plot 3 Tensiometer Readings

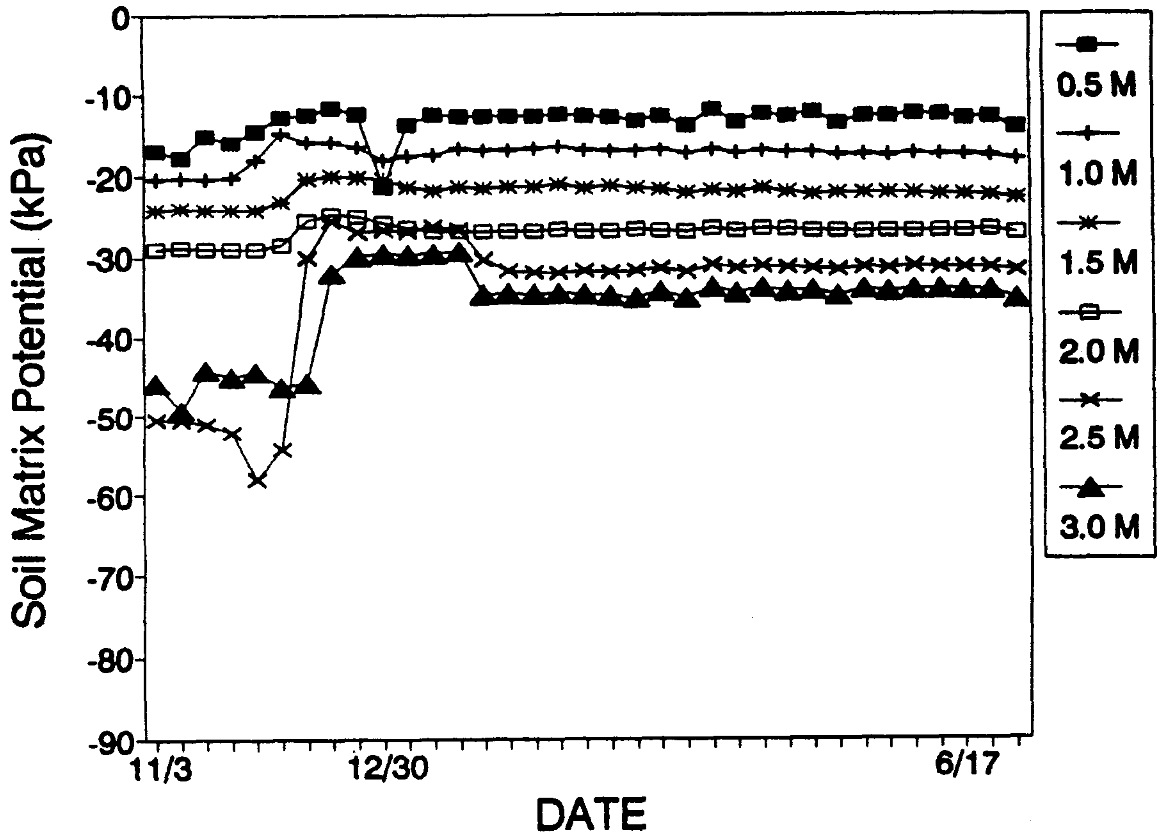


Fig. 6. Plot 4 Tensiometer Readings

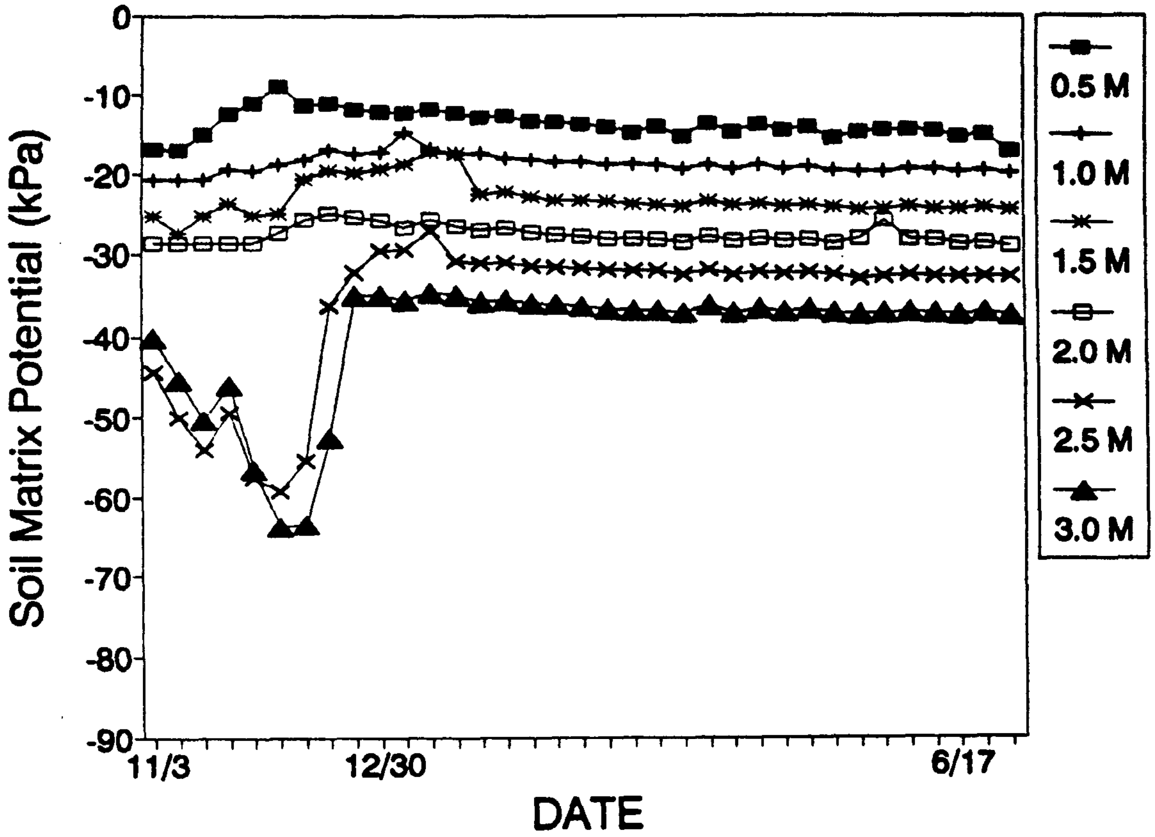


Fig. 7. Plot 5 Tensiometer Readings

Some variation of the soil moisture can be observed in plot 3 relative to plots 1, 2, 4, and 5. This is due to the soil texture difference for plot 3 at the 0.5, 1, and 3-m depths, which have a slightly higher clay percentage.

Plot 5 had water applied only on 12 Jan. and the graphed tensiometer readings indicate a slowly decreasing soil moisture potential throughout the 6-month trial consistent with the gravitational movement of water.

Rate of Tracer Movement

With background Cl levels subtracted, the recovered Cl concentrations from the replicated suction samples have been averaged for each leaching fraction treatment and are recorded by the sampling date. These data are presented in Tables 2-4.

To compensate for differences in dilution between treatments, the Cl concentrations have also been expressed as a percentage of the maximum total Cl recovered from a profile for each treatment, and are presented in Table 5. To examine the rate of the tracer movement, the percentage Cl recovered is expressed relative to the projected dates of the growing season in Figs. 8-13.

As expected, the higher leaching fraction (50% ETo) did move the Cl through the sampling depth in a shorter period of time. After 4 months and approximately 300 mm of irrigation water, all of the tracer pulse had been moved

Table 2. High Leaching Treatment Averages of Recovered Chloride Minus Background Averages

Plots 1 and 2

DATE Actual	1990 Simulated	Accum. Et (mm)	Applied Gallons	mm	Depth (meters) 0.5	1.0	1.5	2.0	Cl ppm 2.5	3.0
02-Jan	26-Mar	0	0	0	0	0	0	0	1	0
08-Jan	01-Apr	4	0	0	0	0	0	0	2	0
12-Jan	05-Apr	19	461	6	8	0	0	0	3	0
15-Jan	08-Apr	32	464	6	51	13	0	0	3	0
18-Jan	11-Apr	45	514	6	73	41	0	0	4	0
22-Jan	15-Apr	63	562	7	57	17	24	0	3	0
25-Jan	18-Apr	78	563	7	25	36	69	0	5	0
29-Jan	22-Apr	98	617	7	120	39	81	0	4	0
01-Feb	25-Apr	114	615	7	53	19	94	3	4	0
08-Feb	02-May	152	1308	16	112	39	85	25	25	0
12-Feb	06-May	175	674	8	100	32	67	42	28	0
19-Feb	13-May	217	1413	17	73	23	32	36	34	2
26-Feb	20-May	268	2232	27	56	34	14	27	35	4
05-Mar	27-May	307	1531	18	35	21	4	22	14	21
12-Mar	03-Jun	355	1594	19	30	27	2	16	16	21
19-Mar	10-Jun	404	1619	19	26	31	0	17	20	19
26-Mar	17-Jun	454	2498	30	18	20	0	7	10	14
02-Apr	24-Jun	505	1704	20	13	16	0	7	6	10
09-Apr	01-Jul	557	1719	21	9	10	0	0	3	7
16-Apr	08-Jul	610	2606	31	11	5	0	3	3	6
23-Apr	15-Jul	662	1726	21	5	6	0	2	2	4
30-Apr	22-Jul	714	1720	21	4	4	0	0	0	3
07-May	29-Jul	764	2500	30	5	4	0	0	0	2
14-May	05-Aug	813	1619	19	2	0	0	0	0	1
21-May	12-Aug	860	1576	19	3	0	0	0	0	1
28-May	19-Aug	904	2233	27	1	0	0	0	0	0
04-Jun	26-Aug	945	1393	17	2	0	0	0	0	0
11-Jun	02-Sep	984	1278	15	3	0	0	0	0	0
18-Jun	09-Sep	1020	1825	22	1	0	0	0	0	0
25-Jun	16-Sep	1053	1103	13	8	0	0	0	0	0
02-Jul	23-Sep	1083	1033	12	1	0	0	0	0	0
09-Jul	30-Sep	1110	943	11	1	0	0	0	0	0
		1110		500						
		100%		45%						

Table 3. Low Leaching Treatment Averages of Recovered Chloride Minus Background Averages

DATE Actual	1990 Simulated	Accum. Et (mm)	Applied Gallons	Applied mm	Plots 3 and 4, ppm Cl, Depth (meters) 0.5	1.0	1.5	2.0	2.5	3.0
02-Jan	26-Mar	0	0	0	2	2	0	0	0	0
08-Jan	01-Apr	4	0	0	2	0	0	0	0	0
12-Jan	05-Apr	19	96	1	3	5	0	0	0	0
15-Jan	08-Apr	32	97	1	0	0	0	0	0	0
18-Jan	11-Apr	45	117	1	0	4	0	0	0	0
22-Jan	15-Apr	63	238	3	263	4	0	0	0	0
25-Jan	18-Apr	78	121	1	120	4	4	2	2	0
29-Jan	22-Apr	98	133	2	184	27	0	24	23	0
01-Feb	25-Apr	114	130	2	47	75	0	34	23	0
08-Feb	02-May	152	281	3	35	103	0	20	17	0
12-Feb	06-May	175	285	3	39	138	0	22	15	0
19-Feb	13-May	217	341	4	78	113	4	10	14	0
26-Feb	20-May	268	467	6	82	110	34	4	12	0
05-Mar	27-May	307	316	4	27	82	91	16	11	3
12-Mar	03-Jun	355	332	4	24	81	90	20	4	3
19-Mar	10-Jun	404	338	4	27	58	60	41	23	4
26-Mar	17-Jun	454	526	6	17	60	54	79	29	6
02-Apr	24-Jun	505	362	4	23	32	39	65	37	5
09-Apr	01-Jul	557	363	4	12	51	26	124	35	5
16-Apr	08-Jul	610	363	4	20	23	19	79	39	5
23-Apr	15-Jul	662	360	4	21	23	27	95	38	5
30-Apr	22-Jul	714	348	4	13	22	35	97	62	6
07-May	29-Jul	764	525	6	18	23	34	91	52	12
14-May	05-Aug	813	351	4	9	25	27	57	49	14
21-May	12-Aug	860	318	4	15	21	33	76	46	17
28-May	19-Aug	904	474	6	4	16	28	30	52	13
04-Jun	26-Aug	945	282	3	17	16	32	16	46	18
11-Jun	02-Sep	984	276	3	6	13	26	37	42	5
18-Jun	09-Sep	1020	396	5	25	11	25	33	51	13
25-Jun	16-Sep	1053	246	3	27	10	20	79	51	12
02-Jul	23-Sep	1083	220	3	46	8	18	24	45	10
09-Jul	30-Sep	1110	206	2	22	8	16	47	39	14
		1110		107						
		100%		9.6%						

Table 4. Simulated Flood Treatment Averages of Recovered Chloride Minus Background Averages

DATE Actual	1990 Simulated	Accum. Et (mm)	Applied Gallons	mm	Plot 5 Cl ppm Depth (meters) 0.5	1.0	1.5	2.0	2.5	3.0
02-Jan		0	0	0	0	0	0	0	0	0
08-Jan	01-Apr	4	0	0	0	2	8	0	0	0
12-Jan	05-Apr	19	26335	316	36	40	78	0	5	0
15-Jan	08-Apr	32	0	0	0	4	0	0	0	0
18-Jan	11-Apr	45	0	0	3	20	2	12	0	0
22-Jan	15-Apr	63	0	0	13	40	3	6	1	0
25-Jan	18-Apr	78	0	0	16	37	1	3	1	0
05-Mar	27-May	307	0	0	98	28	2	6	0	2
26-Mar	17-Jun	454	0	0	1	8	16	6	1	2
16-Apr	08-Jul	610	0	0	5	97	103	5	2	1
07-May	29-Jul	764	0	0	7	44	5	7	3	3
28-May	19-Aug	904	0	0	3	12	22	5	1	0
18-Jun	09-Sep	1020	0	0	10	17	16	7	0	7
09-Jul	30-Sep	1110	0	0	14	34	45	7	2	2
		1110		316						
		100%		28%						

Table 5. Percentage of Maximum Total Chloride Recovered for High and Low Leaching Treatments

DATE		Et	Applied Leaching Fraction				Cl% AVERAGE OF PLOTS 1 & 2 50% ETo						Cl% AVERAGE OF PLOTS 3 & 4 10% ETo					
			50%		10%		meter depth						meter depth					
Actual	Simul.	mm	Gal.	mm	Gal.	mm	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
02-Jan	23-Mar	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	0.7%	0.9%	0.0%	0.0%	0.0%	0.0%
08-Jan	29-Mar	4	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.6%	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%
12-Jan	02-Apr	19	461	6	96	1	2.9%	0.0%	0.0%	0.0%	1.1%	0.0%	1.0%	1.8%	0.0%	0.0%	0.0%	0.0%
15-Jan	05-Apr	32	464	6	97	1	17.9%	4.5%	0.0%	0.0%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
18-Jan	08-Apr	45	514	6	117	1	25.7%	14.3%	0.0%	0.0%	1.3%	0.0%	0.1%	1.5%	0.0%	0.0%	0.0%	0.0%
22-Jan	12-Apr	63	562	7	238	3	19.9%	5.8%	8.5%	0.0%	0.9%	0.0%	98.6%	1.4%	0.0%	0.0%	0.0%	0.0%
25-Jan	15-Apr	78	563	7	121	1	8.6%	12.8%	24.3%	0.0%	1.6%	0.0%	45.1%	1.7%	1.5%	0.7%	0.6%	0.0%
29-Jan	19-Apr	98	617	7	133	2	42.1%	13.6%	28.4%	0.0%	1.3%	0.0%	69.1%	10.1%	0.0%	9.1%	8.7%	0.0%
01-Feb	22-Apr	114	615	7	130	2	18.6%	6.8%	33.0%	1.2%	1.3%	0.0%	17.5%	28.2%	0.0%	12.7%	8.6%	0.0%
08-Feb	29-Apr	152	1308	16	281	3	39.2%	13.5%	29.8%	8.6%	8.9%	0.0%	13.0%	38.6%	0.0%	7.6%	6.2%	0.0%
12-Feb	03-May	175	674	8	285	3	35.2%	11.1%	23.3%	14.5%	9.7%	0.0%	14.8%	51.7%	0.0%	8.3%	5.5%	0.0%
19-Feb	10-May	217	1413	17	341	4	25.6%	7.9%	11.2%	12.5%	11.9%	0.6%	29.1%	42.3%	1.6%	3.6%	5.1%	0.0%
26-Feb	17-May	268	2232	27	467	6	19.8%	11.9%	4.8%	9.3%	12.2%	1.2%	30.7%	41.4%	12.7%	1.6%	4.4%	0.0%
05-Mar	24-May	307	1531	18	316	4	12.3%	7.3%	1.5%	7.8%	4.9%	7.4%	10.2%	30.8%	34.2%	6.1%	4.0%	1.2%
12-Mar	31-May	355	1594	19	332	4	10.6%	9.4%	0.9%	5.7%	5.6%	7.2%	9.1%	30.5%	33.9%	7.3%	1.5%	1.2%
19-Mar	07-Jun	404	1619	19	338	4	9.2%	10.7%	0.1%	5.9%	6.8%	6.7%	10.1%	21.9%	22.5%	15.4%	8.5%	1.5%
26-Mar	14-Jun	454	2498	30	526	6	6.5%	7.1%	0.0%	2.4%	3.4%	5.0%	6.3%	22.6%	20.1%	29.7%	10.9%	2.2%
02-Apr	21-Jun	505	1704	20	362	4	4.4%	5.6%	0.0%	2.4%	2.1%	3.4%	8.6%	11.8%	14.7%	24.4%	14.0%	2.0%
09-Apr	28-Jun	557	1719	21	363	4	3.2%	3.6%	0.0%	0.0%	1.1%	2.5%	4.4%	19.2%	9.6%	46.4%	13.1%	1.7%
16-Apr	05-Jul	610	2606	31	363	4	3.8%	1.9%	0.0%	1.0%	0.9%	2.0%	7.4%	8.7%	7.0%	29.6%	14.5%	1.9%
23-Apr	12-Jul	662	1726	21	360	4	1.9%	2.0%	0.0%	0.8%	0.7%	1.5%	7.7%	8.7%	10.1%	35.8%	14.3%	2.0%
30-Apr	19-Jul	714	1720	21	348	4	1.4%	1.5%	0.0%	0.0%	0.0%	1.0%	4.9%	8.2%	13.3%	36.3%	23.1%	2.1%
07-May	26-Jul	764	2500	30	525	6	1.7%	1.4%	0.0%	0.0%	0.0%	0.6%	6.8%	8.7%	12.9%	34.0%	19.5%	4.3%
14-May	02-Aug	813	1619	19	351	4	0.6%	0.0%	0.0%	0.0%	0.0%	0.2%	3.4%	9.3%	10.2%	21.4%	18.5%	5.3%
21-May	09-Aug	860	1576	19	318	4	1.1%	0.1%	0.0%	0.0%	0.0%	0.2%	5.8%	7.8%	12.6%	28.3%	17.4%	6.3%
28-May	16-Aug	904	2233	27	474	6	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	6.2%	10.5%	11.3%	19.4%	4.9%
04-Jun	23-Aug	945	1393	17	282	3	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	6.4%	5.8%	11.9%	6.0%	17.1%	6.6%
11-Jun	30-Aug	984	1278	15	276	3	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%	5.0%	9.8%	13.9%	15.6%	1.9%
18-Jun	06-Sep	1020	1825	22	396	5	0.3%	0.0%	0.0%	0.0%	0.0%	0.1%	9.4%	4.2%	9.2%	12.2%	19.3%	4.8%
25-Jun	13-Sep	1053	1103	13	246	3	2.7%	0.0%	0.0%	0.0%	0.0%	0.0%	10.3%	3.6%	7.4%	29.6%	19.0%	4.4%
02-Jul	20-Sep	1083	1033	12	220	3	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	17.3%	2.9%	6.8%	9.0%	16.9%	3.8%
09-Jul	27-Sep	1110	943	11	206	2	0.3%	0.0%	0.0%	0.2%	0.0%	0.0%	8.2%	3.1%	6.2%	17.7%	14.6%	5.1%
		1110		500		107												
		100%		45%		9.6%												

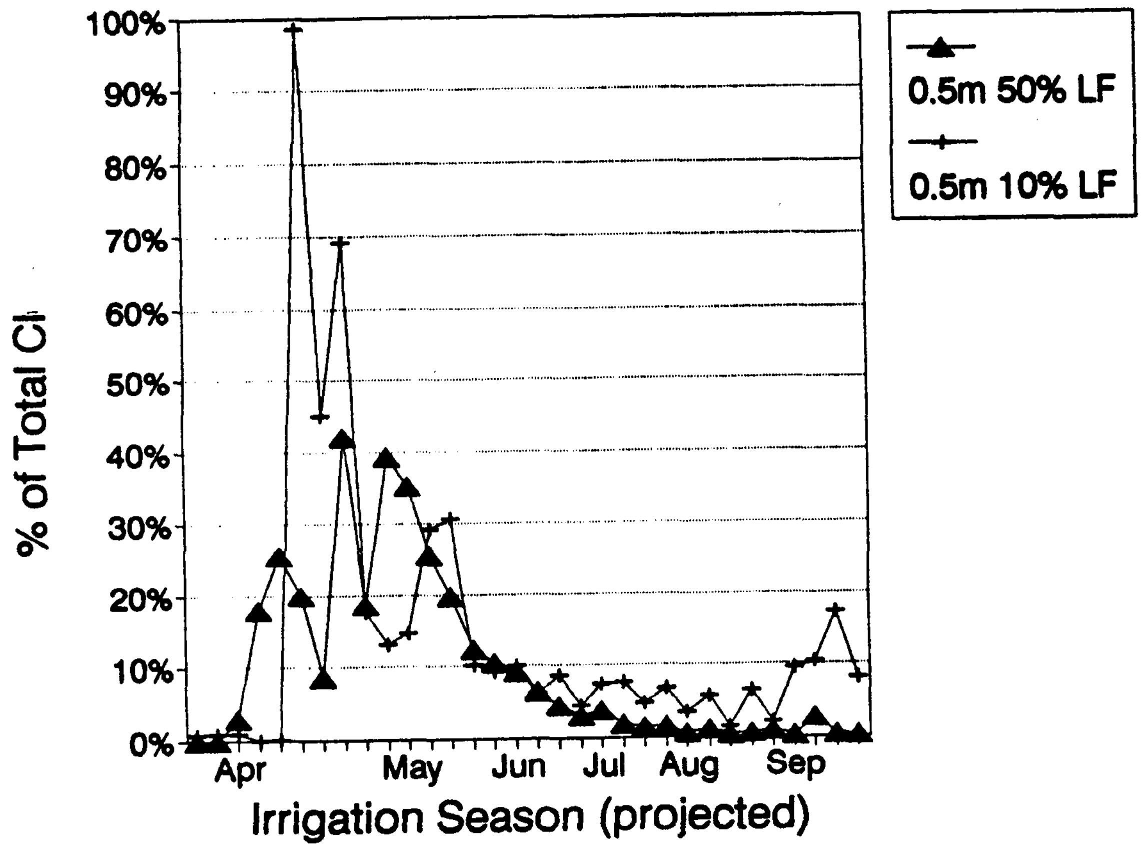


Fig. 8. Seasonal Comparison of Chloride Recovery at 0.5 m

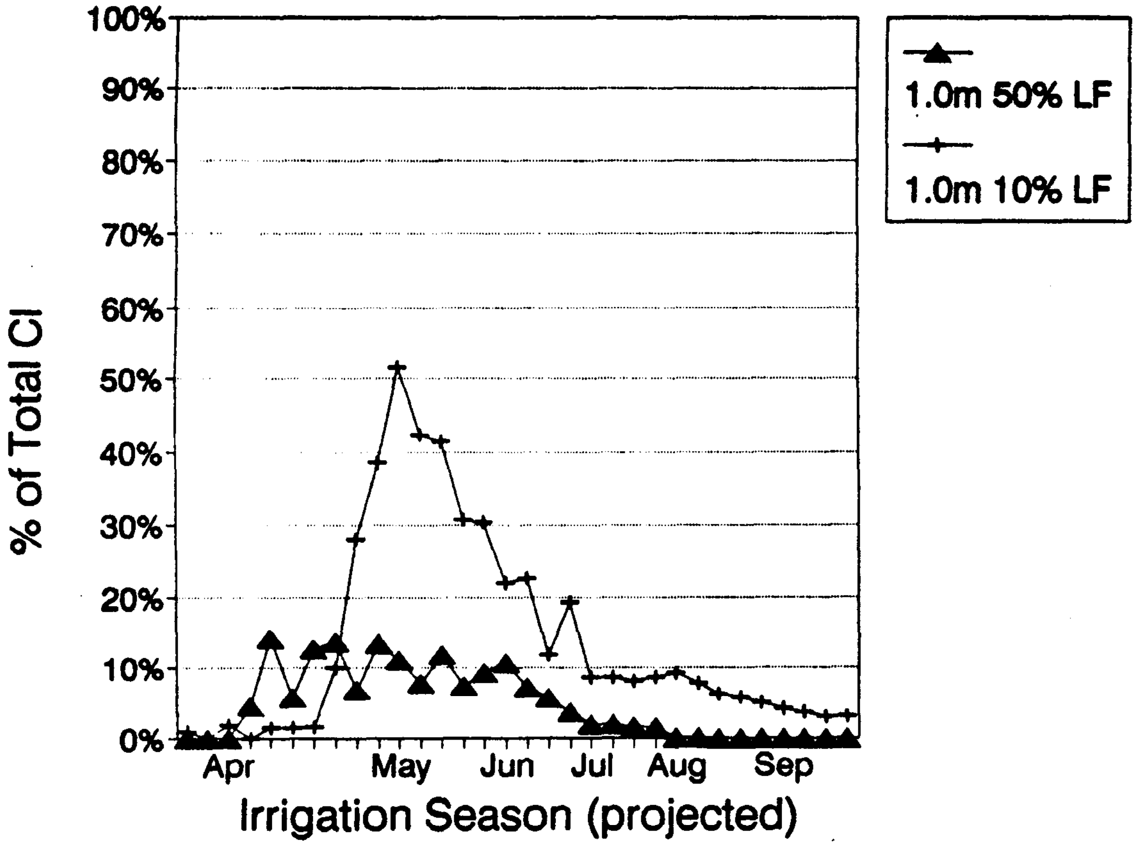


Fig. 9. Seasonal Comparison of Chloride Recovery at 1.0 m

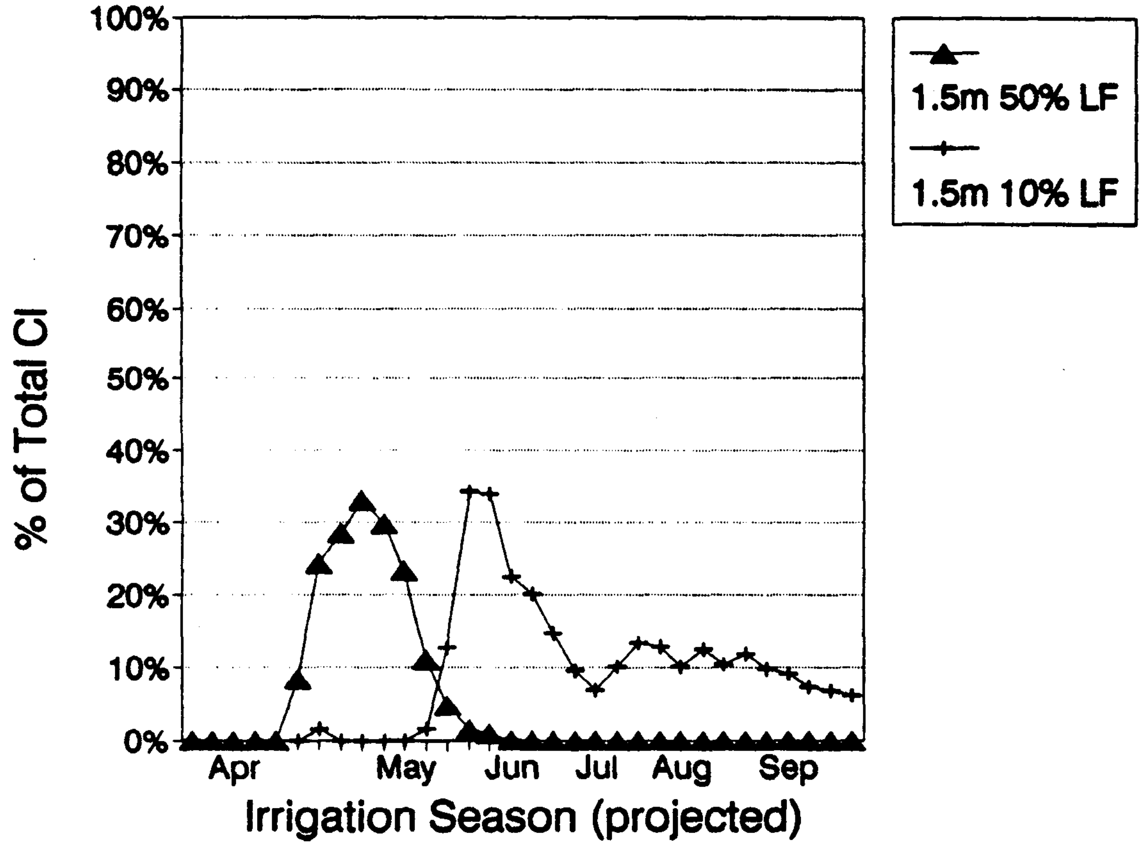


Fig. 10. Seasonal Comparison of Chloride Recovery at 1.5 m

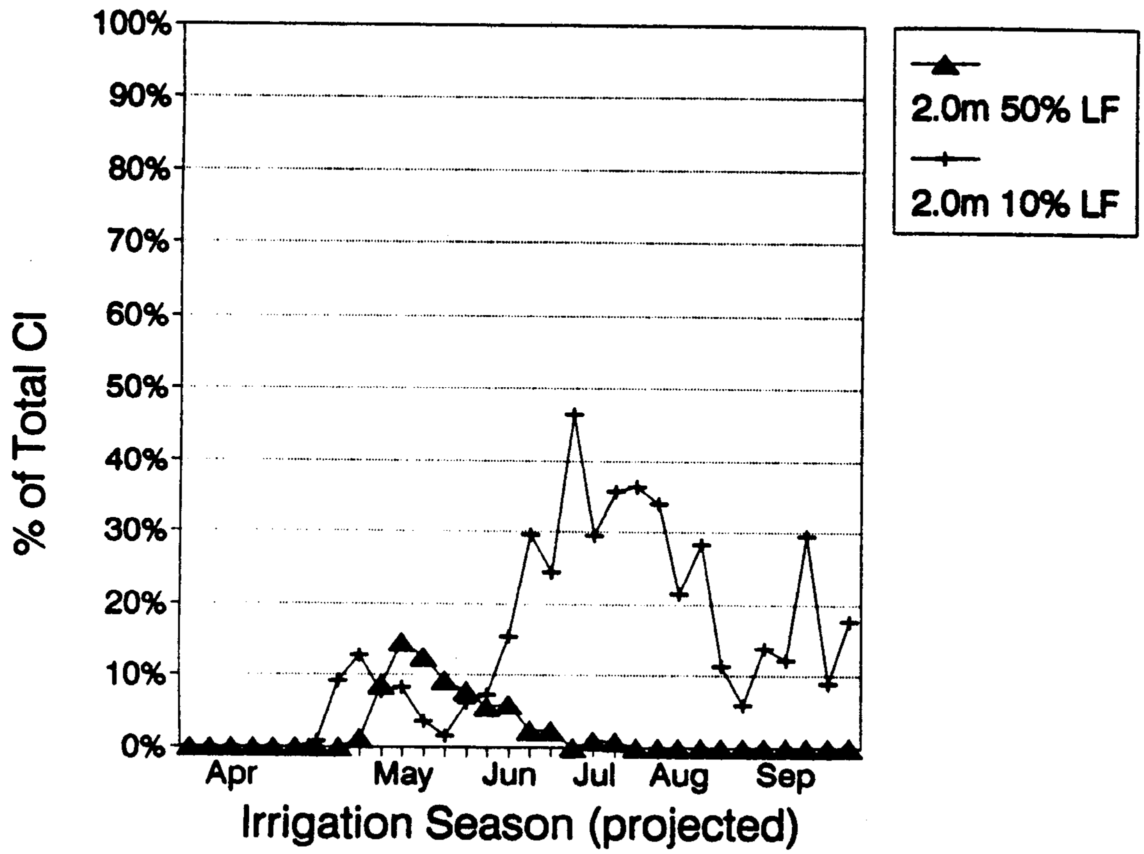


Fig. 11. Seasonal Comparison of Chloride Recovery at 2.0 m

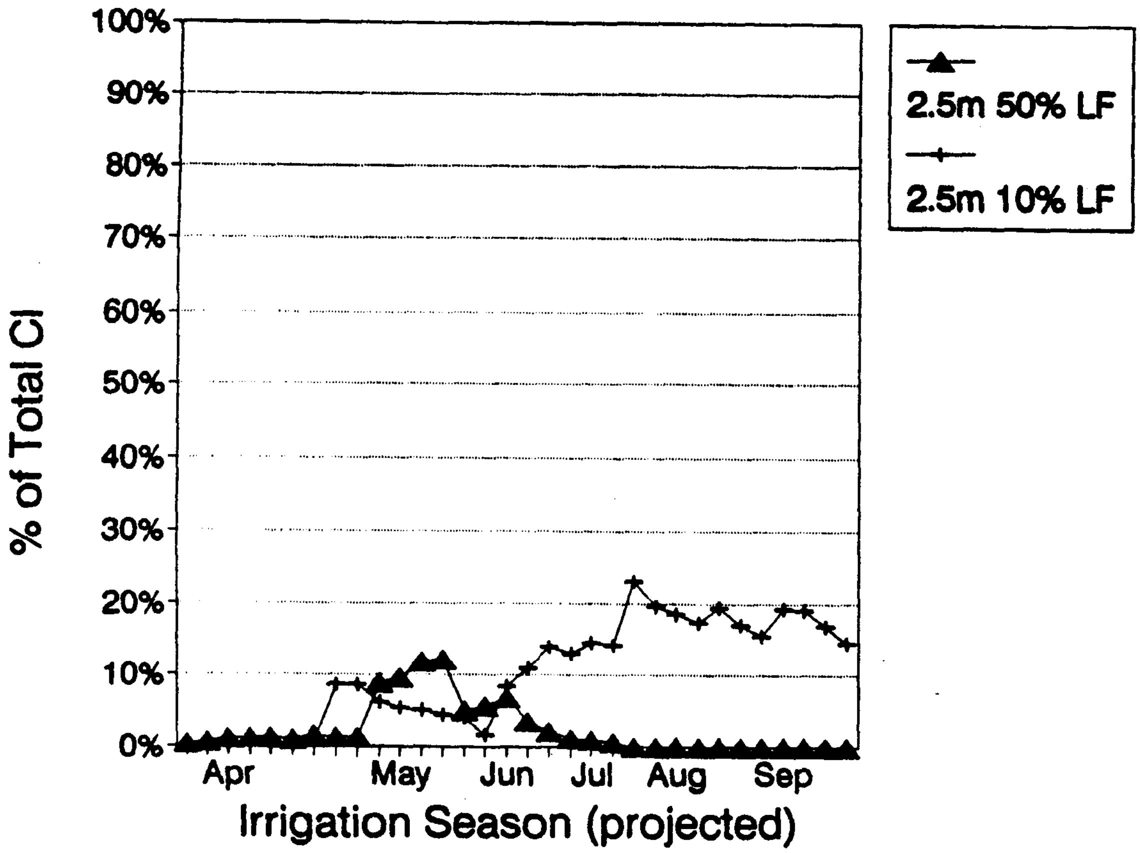


Fig. 12. Seasonal Comparison of Chloride Recovery at 2.5 m

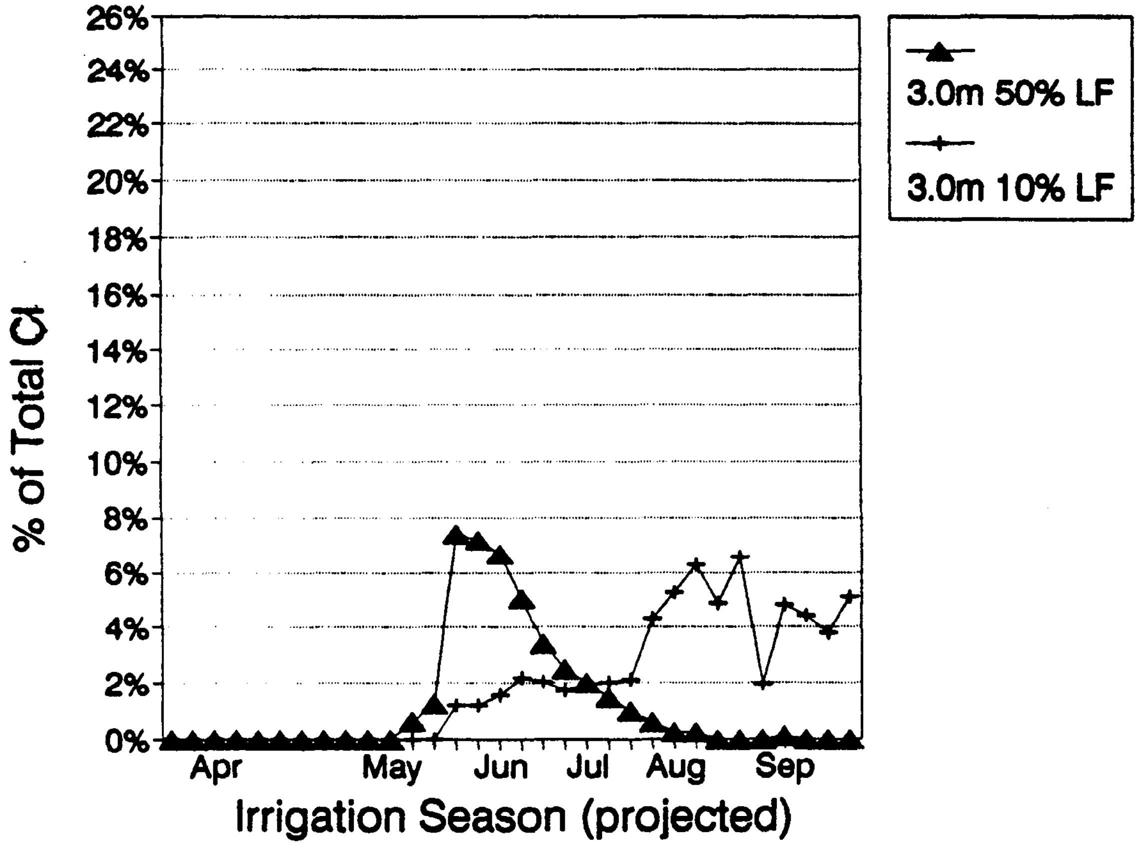


Fig. 13. Seasonal Comparison of Chloride Recovery at 3.0 m

through the 3-m sampling area. The lower leaching fraction (10% ETo) had moved the bulk of the tracer to the 2 to 2.5-m depths at the end of 6 months and 107 mm of irrigation. The simulated flood pre-irrigation had moved the bulk of the tracer to a depth of 1.5 m after a continuous irrigation of 316 mm (28% ETo) early in the season.

A reduction in the amount of water that leached through this soil profile appears to have reduced the rate at which the Cl tracer moved downward. This is most evident as the bulk of the tracer was located above the 3-m depth after 6 months in the 10% leaching treatment, while the tracer had moved below the 3-m depth in the 50% leaching treatment after only 4 months.

Solute Leaching Efficiency

While reducing the leaching fraction does appear to slow the downward transport of solutes, an increase in leaching efficiency was also observed.

It is important to note in this study that at the 2-m depth it required 41 days and 69 mm of water to reach peak Cl concentration for the high leaching treatment, while it required 97 days but only 55 mm for the low leaching treatment. This indicates that frequent applications with small volumes of water may be more efficient at moving solutes through the soil than less frequent applications of larger water volumes. This is perhaps explained by presuming a more intimate mixing of the solutes from the smaller pores to the larger mainstreams prior to leaching, as reported in earlier observations by Biggar and Nielsen (1967) and Hanan (1981). Data from the simulated flood pre-irrigation plot appear to support this premise, as the peak Cl concentration moved rapidly after the 316 mm irrigation was applied, but to a depth of only 1.5 m.

Irrigation Frequency

The relationship between irrigation frequency and water volume on the efficiency of solute leaching in sandy soils merits additional study. Initial observations suggest that additional reductions in solute leaching can be achieved in low-flow irrigation systems by decreasing the frequency of applications. One comparison of low-flow irrigation frequency on leaching efficiency could be to examine an equivalent water volume (10% ETo) leaching fraction applied with two application frequency treatments. The high-frequency treatment could be applied every 2 to 3 days, while the low-frequency treatment should be applied when the soil reaches a critical accumulated moisture depletion.

SUMMARY

Results of well water analysis in California since 1979 indicate that groundwater pollution from non-point sources, such as the application of agricultural chemical to crops, occurs at a faster rate than researchers previously thought. Factors that contribute to pollutant mobility in soil include: (a) use and method of application; (b) physical and chemical characteristics of pollutants; (c) soil type; (d) rainfall; and (e) irrigation practices.

The objective of this study was to examine the effects of limiting applied irrigation leaching fractions on the potential for reducing groundwater contamination in sandy soils. Chloride was used as a tracer to model the soluble fraction of a pollutant as it dissolves or its soluble constituents as it biodegrades.

The applied 50% ETo leaching fraction moved the Cl tracer beyond the 3-m sample depth after only 4 months of a projected irrigation season. Reducing the applied leaching fraction to 10% ETo slowed the tracers downward movement so that the Cl pulse was contained within the 3-m sample depth at the end of the 6-month irrigation season, but there also is evidence to suggest that leaching efficiency increases with smaller irrigation amounts.

By reducing the rate at which contaminants travel through the soil toward the aquifer, there would be more potential for residues to dissipate through microbial decomposition, chemical degradation, or volatilization as these materials would remain in the biologically active upper soil layer for a longer period of time. The positive result of this action would be that less of the contaminant would be transported from the upper to lowers layer of soil, aiding in the reduction of groundwater contamination.

REFERENCES

REFERENCES

Biggar, J. W. and Nielsen, D. R. (1962). Miscible displacement: II. Behavior of tracers. Soil Sci. Soc. Amer. Proc. 26:125-128.

Biggar, J. W. and Nielsen, D. R. (1967). Miscible displacement and leaching phenomenon, p. 254-274. In R.M. Hagan et al. (ed.) Irrigation of agricultural lands. Agron. Mono. 11. Amer. Soc. Agron., Madison, Wis.

Biggar, J. W. and Nielsen, D. R. (Feb. 1976). Spatial variability of the leaching characteristics of a field soil. Water Resources Research 12:78-84.

Bodman, G. B. and Colman, E. A. (1944). Moisture and energy conditions during downward entry of water into soils. Soil Sci. Soc. Am. Proc. 8:116-122.

CDFA (California Department of Food and Agriculture) (July 1985) Environmental Hazards Assessment Program. Agricultural pesticide residues in California well water: Development and summary of a well inventory data base for non-point sources. CDFA, Sacramento, CA.

CDFA (California Department of Food and Agriculture) (Dec. 1 1990) Environmental Hazards Assessment Program. Sampling for pesticide residues in California well water: 1990 update well inventory data base. CDFA, Sacramento, CA.

Cassel, D. K. (1971). Water and solute movement in Svea loam for two water management regimes. Soil Sci. Soc. Am. Proc. 35:859-866.

DWR (California Department of Water Resources) (Nov. 1987). California water: Looking to the future. Bulletin 160-87. DWR, Sacramento., CA.

Darcy, H. (1856). "Les Fontaines Publique de la Ville de Dijon." Dalmont, Paris.

APPENDIX

Table 6. Raw Data for Plot 1, High Leaching Treatment

ppm Cl

1990 DATE Actual	Simulated	Accum. Et mm	Applied (50% Et) Gal.	mm	Plot 1 0.5 m A	B	C	Plot 1 1.0 m A	B	C	Plot 1 1.5 . m A	B	C	Plot 1 2.0 m A	B	C	Plot 1 2.5 m A	B	C	Plot 1 3.0 m A	B	C
09-Dec		0	0	0	6	9	4	25	11	7		6	8		5	9	7	5		4	8	17
14-Dec		0	0	0	6	6	4	16	9		5	4	4	4	4	4	9	3	10	35		18
21-Dec		0	0	0	13	5	4	16	7	9	4	4	5	4	3	4	15	3	8	11	51	8
29-Dec		0	0	0	4	12	8	15	7	7	4	3	5	3	3	3	28	4	6	6	28	7
02-Jan		0	0	0			3	14	6	7	4	4	6	3	3	3	37	3	5	4	25	7
08-Jan	01-Apr	4	0	0			3	14	12	9	3	4	7	3	3	3	40	3	5	5	24	7
12-Jan	05-Apr	19	461	6			4	13	12	8	3	4	8	3	3	4	47	4	6	4	25	7
15-Jan	08-Apr	32	464	6		5	3	11	11	6	4	4	6	4	3	4	47	5	5	4	25	7
18-Jan	11-Apr	45	514	6			8	11	9	7	4	5	9	4	4	4	48	6	6	5	26	8
22-Jan	15-Apr	63	562	7			31	11	8	7	4	4	62	3	4	4	40	7	6	5	24	7
25-Jan	18-Apr	78	563	7			60	11	6	5	4	5	124	6	4	6	24	35	6	4	26	7
29-Jan	22-Apr	98	617	7			174	11	8	6	5	44		3	6	8	21	32	7	4	26	6
01-Feb	25-Apr	114	615	7			89	14	17	5	9	121	142	4	17	24	20	35	5	4	27	5
08-Feb	02-May	152	1308	16	365	195	82	30	209	5	50	121	78	99	39	35	37	95	4	7	30	4
12-Feb	06-May	175	674	8		266	92	53	110	6	99	60	53	163	39	38	89	57	5	15	32	5
19-Feb	13-May	217	1413	17		177	99	43	99	6		39	41	92	41	24	160	38	10	39	33	6
26-Feb	20-May	268	2232	27		156	53	46	156	16	36	32	19	53	31	14	156	21	47	43	29	14
05-Mar	27-May	307	1531	18		71	57	35	46	51	12	14	15	19	27	10	71		10	40	27	50
12-Mar	03-Jun	355	1594	19		57	46	51	43	85	11	11	12	8	11	7	46	8	60	26	35	39
19-Mar	10-Jun	404	1619	19		42	54	40	38	113	9	8	10	6	12	6	28	6	82	21	48	38
26-Mar	17-Jun	454	2498	30		31	39	36	26	74	7	7	9	5	8	4	19	5	43	14	54	25
02-Apr	24-Jun	505	1704	20		23	27	30	17	70	6	6	9	5	5	4	14	5	32	11	49	18
09-Apr	01-Jul	557	1719	21		17	22	24	16	50	6	5	8	4	5	4	18	6	21	9	46	19
16-Apr	08-Jul	610	2606	31		14	18	18	6	38	5	5	9	4	5	4	11	6	7	42	13	15
23-Apr	15-Jul	662	1726	21		13	16	18	19	32	6	5	7	5	6	5	10	5	19	8	43	12
30-Apr	22-Jul	714	1720	21		11	14	15	28	27	5	5	8	4	5	4	8	5	16	5	42	14
07-May	29-Jul	764	2500	30		11	13	15	19	25	8	5	8	5	7	5	10	5	13	8	43	11
14-May	05-Aug	813	1619	19		8	11	15	11	20	5	5	5	5	4	4	8	4	11	6	39	9
21-May	12-Aug	860	1576	19		8	10	12	9	18	5	5	6	4	4	5	8	5	7	5	35	9
28-May	19-Aug	904	2233	27	528	11	9	12	7	16	5	4	5	5	4	5	7	4	8	4	32	9
04-Jun	26-Aug	945	1393	17		9	8	12	9	15	5	5	6	5	5	8	8	5	8	7	31	8
11-Jun	02-Sep	984	1278	15		7	7	12	6	11	6	4	5	4	4	6	8	5	8	5	26	6
18-Jun	09-Sep	1020	1825	22		7	7	14	8	9	8	10	7	7	5	6	9	7	8	6	24	6
25-Jun	16-Sep	1053	1103	13		6	7	8	13	8	5	5	6	5	4	6	8	6	7	5	11	8
02-Jul	23-Sep	1083	1033	12		6	6	10	8	7	6	6	8	4	4		13	5	7	5	20	6
09-Jul	30-Sep	1110	943	11		6	5	11	8	7	5	5	5	5	4	19	8	5	8	5	18	5
		1110		500																		
		100%		45%																		

Table 7. Raw Data for Plot 2, High Leaching Treatment

ppm Cl

1990 DATE Actual	Simulated	Accum. Et mm	Applied (50% Et) Gal.	mm	Plot 2 0.5 m A	B	C	Plot 2 1.0 m A	B	C	Plot 2 1.5 m A	B	C	Plot 2 2.0 m A	B	C	Plot 2 2.5 m A	B	C	Plot 2 3.C m A	B	C
09-Dec		0	0	0	5	9	6	4	14	5	7	10	4	9	11	10	10	10	11	4	9	2
14-Dec		0	0	0	4	6	4	4	15	4	5	8	3	13	6	11	4	3	17	2	10	3
21-Dec		0	0	0	4	6	4	4	13	5	3	6	3	10	4	7	3	4	12	3	10	3
29-Dec		0	0	0	4	5	3	4	13	5		5	4	9	4	5	3	4	10	3	7	4
02-Jan		0	0	0	4	5	3	3	11	4	4		3	6	3	4	3	4	9	3	5	3
08-Jan	01-Apr	4	0	0	4	6	5	7	18	5	4		3	7	3	4	3	3	8	3	6	3
12-Jan	05-Apr	19	461	6	4	5	67	11	16	6	7		3	7	4	5	4	3	8	3	6	3
15-Jan	08-Apr	32	464	6	6	5	323	89	19	4	4	4	3	7	4	4	4	3	8	3	6	3
18-Jan	11-Apr	45	514	6	5	5	457	177		9			4	8	5	5	5	4	9	4	7	4
22-Jan	15-Apr	63	562	7	5	5	297	39	13	82	3	124	3	9	4	5	5	4	9	3	6	3
25-Jan	18-Apr	78	563	7	5	7		16	10	227	5	326	7	8	4	4	5	4	9	3	8	3
29-Jan	22-Apr	98	617	7	8	31	220	9	11	248		202	110	8	4	4	7	3	8	2	6	3
01-Feb	25-Apr	114	615	7	17	55	39	5	8	138	43	128	177	8	4	4	17	4	7	4	6	4
08-Feb	02-May	152	1308	16	7	60	21	4	8	57	149	54	113	7	7	4	43	39	7	3	7	3
12-Feb	06-May	175	674	8	41	67	17	4	14	85	142	40	60	7	60	4	36	45	7	3	7	3
19-Feb	13-May	217	1413	17	37		19	4	23	42	57		27	9	99	11	34	29	6	4	6	12
26-Feb	20-May	268	2232	27	57	13	14	4	42	21	23	15	12	49	28	46	33	18	6	6	10	13
05-Mar	27-May	307	1531	18	25	45	8	4	53	18	15	17	7	43	41	55	13	13	10	12	46	46
12-Mar	03-Jun	355	1594	19		50	7	4	45	15	9	20	6	58	27	48	6	11	38	17	55	45
19-Mar	10-Jun	404	1619	19	21	45	6	4	59	11	7	16	6	110	7	21	5	8	61	20	48	34
26-Mar	17-Jun	454	2498	30	23	35	7	4	54	10	6	16	4	53	9	15	4	6	54	23	40	24
02-Apr	24-Jun	505	1704	20	21	34	5	5	47	9	4	14	4	58	7	12	4	6	48	25	34	15
09-Apr	01-Jul	557	1719	21	20	29	6	3	43	8	4	12	5	6	6	10	4	4	38	24	29	9
16-Apr	08-Jul	610	2606	31	36	34	7	5	38	9	4	11	4	38	6	10	5	5	41	26	24	8
23-Apr	15-Jul	662	1726	21	11	31	6	5	33	9	5	11	4	35	6	9	5	5	36	26	19	7
30-Apr	22-Jul	714	1720	21	12	27	7	5	25	8	4	9	5	16	5	8	4	4	26	25	13	6
07-May	29-Jul	764	2500	30	16	29	7	6	31	9	4	8	4	17	5	7	5	4	22	21	11	5
14-May	05-Aug	813	1619	19	7	25	5	4	26	5	4	6	5	15	6	6	4	5	19	18	8	5
21-May	12-Aug	860	1576	19	12	27	6	4	24	8	4	6	4	12	5	7	4	4	15	18	8	5
28-May	19-Aug	904	2233	27	11	15	7	4	18	5	4	5	4	9	4	5	4	4	14	15	8	4
04-Jun	26-Aug	945	1393	17	7	21	9	3	18	7	5	6	4	8	5	6	4	4	11	14	7	5
11-Jun	02-Sep	984	1278	15		22	7	5	19	7	4	5	4	17	5	5	4	4	11	14	6	4
18-Jun	09-Sep	1020	1825	22		15	6	5	17	6	5	5	4	8	7	6	4	5	10	12	12	5
25-Jun	16-Sep	1053	1103	13	41	11	22	7	16	9	5	4	4	11	7	5	5	4	10	13	6	5
02-Jul	23-Sep	1083	1033	12	11	16	8	4	14	6	4	4	4	5	4	6	4	4	11	13	6	5
09-Jul	30-Sep	1110	943	11	10	16	6	5	14	7	6	5	5	6	5	5	4	4	11	14	6	5
		1110		500																		
		100%		45%																		

Table 8. Raw Data for Plot 3, Low Leaching Treatment

ppm Cl

1990 DATE Actual	Simulated	Accum. Et mm	Applied (50% Et) Gal.	mm	Plot 3 0.5 m A	B	C	Plot 3 1.0 m A	B	C	Plot 3 1.5 m A	B	C	Plot 3 2.0 m A	B	C	Plot 3 2.5 m A	B	C	Plot 3 3.0 m A	B	C
09-Dec		0	0	0	6	11	16	4	5	11	6	23	4	8	4	10	6					
14-Dec		0	0	0	5	3	12	3	4	8	4	13	3	6	3	3	2	3	5	5		
21-Dec		0	0	0	7	3	12	3	3	7	4	10	3	3	3	4	3	3	4	4	50	13
29-Dec		0	0	0		22	11	20	3	6	3	7	4	4	4	3	3	3	5	6	7	5
02-Jan		0	0	0		25	11	37	3	6	3	6	3	3	3	3	4	3	3	3	5	4
08-Jan	01-Apr	4	0	0			19		3	6	4	6	3	4	3	3	4	4	3	3	5	4
12-Jan	05-Apr	19	96	1			18	50	4	6	4	7	4	4	4	4	3	5	3	3	5	4
15-Jan	08-Apr	32	97	1		1156	16		4	6	3	6	4	3	4	3	3	4	3	4	5	4
18-Jan	11-Apr	45	117	1			15	44	4	7	4	7	4	4	4	5	4	5	4	5	5	5
22-Jan	15-Apr	63	238	3		386	15	43	4	6	3	6	4	3	4	3	4	4	4	4	5	4
25-Jan	18-Apr	78	121	1		255		46	5	7	4	6	6		4	4	4	5	4	4	4	4
29-Jan	22-Apr	98	133	2		269	177	181	4	7	4	6	6	6	5	4	4	5	4	4	5	4
01-Feb	25-Apr	114	130	2		87	64	472	4	6	4	6	10		3	4	4	5	4	6	4	4
08-Feb	02-May	152	281	3	28	14	32	638	5	5	3	6	13	5	4	4	6	5	8	5	5	5
12-Feb	06-May	175	285	3	4	43	28	837	14	7	4	6	21	6	7	4	6	5	4	5	5	5
19-Feb	13-May	217	341	4	17	46	28	486	216	5	3	6	50	4	5	4	4	6	3	4	4	11
26-Feb	20-May	268	467	6	28	26	23	206	475	6	4	6	206	6	7	6	6	5	3	6	4	5
05-Mar	27-May	307	316	4	5	16	22	103	401	6	3	5	489	7	10	4	7	6	4	4	4	
12-Mar	03-Jun	355	332	4	15	8	30	40	277	7	5	6	330	6	18	7	9	8	6	6	5	6
19-Mar	10-Jun	404	338	4	23	15	57	23		9	5	5	209	5	117	5	14	10	5	5	5	10
26-Mar	17-Jun	454	526	6	11	12	53	15	34	16	4	5	138	5	202	22	29	50	7	4	4	5
02-Apr	24-Jun	505	362	4	6	19	61	11	17	30	4	6	149	8	213	66	55	92	23	4	4	5
09-Apr	01-Jul	557	363	4	2	9	57	9	12	46	6	9	71		255	152	25	82	60	4	4	4
16-Apr	08-Jul	610	363	4		25	32	9	11	14	9	20	50	7	199	202	46	28	96	7	8	5
23-Apr	15-Jul	662	360	4	67	14	43	7	8	68	17	44	41	6	238	220	57	652	39	11	20	5
30-Apr	22-Jul	714	348	4		11	46	8	9	66	27	76	27	7	230	273	80	65	128	24	33	5
07-May	29-Jul	764	525	6		13	55	14	6	61	35	60	18	10	223	241	79	67	39	42	42	5
14-May	05-Aug	813	351	4		8	41		5	50	47	46	8	4	145	145	64	51		47	48	5
21-May	12-Aug	860	318	4		11	56	6	5	50	54	80	6	8	156	245	4	58	85	66	47	5
28-May	19-Aug	904	474	6	34	8	21	6	6	38	58	61	5	12	44	92	73	50	70	54	40	4
04-Jun	26-Aug	945	282	3		20	46	6	6	38	72	61	5	25		865	72	58	32	81	41	6
11-Jun	02-Sep	984	276	3		11		5	6	34	60	51	5	33	67	99	28	59	71	16	40	5
18-Jun	09-Sep	1020	396	5	32	11	121	9	7	31	63	41	6	44	57	82	71	58	71	58	38	6
25-Jun	16-Sep	1053	246	3	74	21	82	6	6	29	54	33	5	67	63	330	85	63	60	56	37	6
02-Jul	23-Sep	1083	220	3		64	82	6	5	31	44	32	4	60	37	1578	79	62	54	56		6
09-Jul		1110	206	2	11	23	72	9	12	27	50	25	5	85	40	152	35	62	63	57	45	7
		1110		107																		
		100%		9.6%																		

Table 9. Raw Data for Plot 4, Low Leaching Treatment

ppm Cl

1990 DATE Actual	Simulated	Accum. Et mm	Applied (50% Et) Gal.	mm	Plot 4 0.5 m A	B	C	Plot 4 1.0 m A	B	C	Plot 4 1.5 m A	B	C	Plot 4 2.0 m A	B	C	Plot 4 2.5 m A	B	C	Plot 4 3.0 m A	B	C
09-Dec		0	0	0	7	6	4	3	4	4	4	5	10	4	13	10	6	10	14	16		
14-Dec		0	0	0	4	5	4	7	3	4	3	3	13	3	8	4	4	4	4	12	8	46
21-Dec		0	0	0	5	4	3	3	3	4	3	3	9	3	4	4	3	3	4	9	4	32
29-Dec		0	0	0	4	3	10	3	3	4	3	3	6	15	5	4	12	3	4	9	4	22
02-Jan		0	0	0	3	3	19	3	3	3	3	2	5	14	5	3	11	3	3	8	5	21
08-Jan	01-Apr	4	0	0	4	5	17	3	3	3	3	3	4	16	5	3	10	3	3	7	9	21
12-Jan	05-Apr	19	96	1	4	11	17	4	3	4	3	3	4	19	6	3	10	3	3	7	9	22
15-Jan	08-Apr	32	97	1	3	9	4	3	3	3	3	2	4	20	6	3	9	2	2	5	9	19
18-Jan	11-Apr	45	117	1	4	5	3	4	4	5	4	4	5	20	6	4	11	4	3	8	9	24
22-Jan	15-Apr	63	238	3	3	4	1039	4	3	4	4	3	4	22	6	3	10	4	4	5	8	21
25-Jan	18-Apr	78	121	1	4	5		4	4	4	4	3	46	33	6	4	33	3	3	6	9	23
29-Jan	22-Apr	98	133	2	2	8	496	4	3	4	3	3	4	167	6	4	163	3	3	6	9	23
01-Feb	25-Apr	114	130	2	3	34	85	4	3	3	4	3	4	223	6	4	160	3	4	6	9	23
08-Feb	02-May	152	281	3	3	160	41	3	4	4	4	3	4	142	7	4	121	4	4	6	9	21
12-Feb	06-May	175	285	3	3	209	19	4	4	4	4	3	4	152	8	4	110	4	4	5	9	21
19-Feb	13-May	217	341	4	2	390	53	4	3	4	9	5	3	74	11	4	103	3	5	5	9	24
26-Feb	20-May	268	467	6	2	457	25	22	4	4	39	4	5	27	27	3	85	4	11	5	10	31
05-Mar	27-May	307	316	4	3	163	24	1285	10	4	99	9	3	71	51	7	57	4	33	6	31	43
12-Mar	03-Jun	355	332	4	5	145	13	156	53	10	234	24	5	48	60	35	43	6	5	6	30	44
19-Mar	10-Jun	404	338	4	3	124	9	135	184	37	156	41	5	39	63	74	51	7	103	5	44	36
26-Mar	17-Jun	454	526	6	3	82	9	57	184	110	174	54	8	33	61	209	52	13	78	6	52	37
02-Apr	24-Jun	505	362	4	4	110	8	60		64	67	60	11	29	53	78	49	24	35	8	54	31
09-Apr	01-Jul	557	363	4	4	62	7	40	99	156	46	67	16	25	47	117	48	34	14	11	49	28
16-Apr	08-Jul	610	363	4	7	85	11	29	57	74	64	7	23	28	44	50	47	45	24	17	47	27
23-Apr	15-Jul	662	360	4	6	54	9	22	35	53	51	259	32	25	34	106	44	47		22	44	26
30-Apr	22-Jul	714	348	4	8	41	13	17	57	28	48	59	37	26	31	71	41	48	62	21	37	20
07-May	29-Jul	764	525	6	9	55	13	13	43	57	46	59	50	29	28	70	47	57	77	26	39	21
14-May	05-Aug	813	351	4	10	36	5	9	31	81	33	39	51	28	24	53	48	58	72	24	41	25
21-May	12-Aug	860	318	4	11	44	7	10	25	83	28	38	56	30	22	49	55	60	70	26	42	21
28-May	19-Aug	904	474	6	8	15	6	8	21	74	25	24	56	29	21	40	51	59	62	24	41	21
04-Jun	26-Aug	945	282	3	11	45	18	8	18	72	24	21	68	33	21	35	49	60	57	25	41	17
11-Jun	02-Sep	984	276	3	9	31		9	15	65	22	20	60	30	21	29	44	53		22	39	15
18-Jun	09-Sep	1020	396	5	10	28		7	13	54	21	22	56	26	20	23	45	61	56	26	38	17
25-Jun	16-Sep	1053	246	3	22	16		7	13	51	20	14	53	24	20	26	45	53	52	25	37	16
02-Jul	23-Sep	1083	220	3	57	28		7	12	40	17	12	61	18	19	24	33	48	49	26	32	15
09-Jul		1110	206	2	44	26	25	8	12	36	20	11	49	19	20	24	33	48	46	27	36	15
		1110		107																		
		100%		9.6%																		

Table 10. Raw data for Plot 5, Simulated Flood Treatment

ppm Cl

1990 DATE Actual	Simulated	Accum Et mm	Applied (50% Et) Gal.	mm	Plot 5 0.5 m A	B	C	Plot 5 1.0 m A	B	C	Plot 5 1.5 m A	B	C	Plot 5 2.0 m A	B	C	Plot 5 2.5 m A	B	C	Plot 5 3.0 m A	B	C
09-Dec		0	0	0	8	5	5	8	4	6	46	4	22	10		5	16		11		3	
14-Dec		0	0	0	6	3	4	4	3	3	8	3	13	10	38	3	14	6	6	18	7	16
21-Dec		0	0	0	8	3	4	4	3	4	7	3	9	6	13	4	11	3	5	13	8	5
29-Dec		0	0	0	10	3	5	4	22	4	9	5	9	6	14	6	8	3	4	10	7	5
02-Jan		0	0	0		3		3	25	3	11	5	10	4	14	6	7	3	4	9	7	4
08-Jan	01-Apr	4	0	0		3		4	28	4	57	4	10	4	16	8	7	3	4	9	7	4
12-Jan	05-Apr	19	26335	316		46		74	9	67	266	4	12	3	14	6	6	4	41	8	7	4
15-Jan	08-Apr	32	0	0	6	15	5	10	4	28	4	3	8	5	28	4		4	16	7	20	7
18-Jan	11-Apr	45	0	0	6	19		13	4	74	27	4	22	29	46	3	7	3	6	5	17	4
22-Jan	15-Apr	63	0	0	6	40		30	3	117	30	3	23	20	36	5	31	3	5	4	28	3
25-Jan	18-Apr	78	0	0	6	46		38	3	99	25	3	23	19	27	3	28	4	7	4	29	4
29-Jan	22-Apr	98	0	0																		
01-Feb	25-Apr	114	0	0																		
08-Feb	02-May	152	0	0																		
12-Feb	06-May	175	0	0																		
19-Feb	13-May	217	0	0																		
26-Feb	20-May	268	0	0																		
05-Mar	27-May	307	0	0	15	9	300	19	6	89	23	5	25	27	27	5	18	6	13	8	23	11
12-Mar	03-Jun	355	0	0																		
19-Mar	10-Jun	404	0	0																		
26-Mar	17-Jun	454	0	0	10	10	14	19	4	32	60	5	31	25	32	4	17	7	16	7	28	8
02-Apr	24-Jun	505	0	0																		
09-Apr	01-Jul	557	0	0																		
16-Apr	08-Jul	610	0	0	7	22	16	20	4	298	316	6	34	26	27	5	18	7	16	7	24	9
23-Apr	15-Jul	662	0	0																		
30-Apr	22-Jul	714	0	0																		
07-May	29-Jul	764	0	0	9	30	14	21	10	131		8	35	27	30	6	18	10	17	8	26	10
14-May	05-Aug	813	0	0																		
21-May	12-Aug	860	0	0																		
28-May	19-Aug	904	0	0	6	23	11	18	3	47	67	7	39	23	27	6	16	8	15	7	20	8
04-Jun	26-Aug	945	0	0																		
11-Jun	02-Sep	984	0	0																		
18-Jun	09-Sep	1020	0	0	9	35	16	20	4	55	53	8	35	26	28	8	16	9	11	8	39	10
25-Jun	16-Sep	1053	0	0																		
02-Jul	23-Sep	1083	0	0																		
09-Jul	30-Sep	1110	0	0	10	42	19		5	82	149	2	32	25	29	10	17	12	13	9	21	12
		1110		316																		
		100%		28%																		

Table 11. Soil Textural Percentages of Experimental Plots

PLOT 1

SAMPLE DEPTH	% SAND	% SILT	% CLAY
0.5 m	91.0%	4.0%	5.0%
1.0 m	91.0%	4.0%	5.0%
1.5 m	91.0%	4.0%	5.0%
2.0 m	89.0%	4.0%	7.0%
2.5 m	90.0%	4.0%	6.0%
3.0 m	79.0%	9.0%	12.0%

PLOT 2

SAMPLE DEPTH	% SAND	% SILT	% CLAY
0.5 m	90.0%	4.0%	6.0%
1.0 m	90.0%	4.0%	6.0%
1.5 m	91.0%	4.0%	5.0%
2.0 m	91.0%	4.0%	5.0%
2.5 m	88.0%	4.0%	5.0%
3.0 m	93.0%	5.0%	7.0%

PLOT 3

SAMPLE DEPTH	% SAND	% SILT	% CLAY
0.5 m	88.0%	4.0%	8.0%
1.0 m	88.0%	4.0%	8.0%
1.5 m	89.0%	4.0%	7.0%
2.0 m	90.0%	3.0%	7.0%
2.5 m	90.0%	4.0%	6.0%
3.0 m	85.0%	7.0%	8.0%

PLOT 4

SAMPLE DEPTH	% SAND	% SILT	% CLAY
0.5 m	95.0%	4.0%	1.0%
1.0 m	89.0%	6.0%	5.0%
1.5 m	89.0%	6.0%	5.0%
2.0 m	88.0%	7.0%	5.0%
2.5 m	92.0%	5.0%	3.0%
3.0 m	90.0%	6.0%	4.0%

PLOT 5

SAMPLE DEPTH	% SAND	% SILT	% CLAY
0.5 m	89.0%	8.0%	3.0%
1.0 m	90.0%	5.0%	5.0%
1.5 m	89.0%	6.0%	5.0%
2.0 m	87.0%	5.0%	8.0%
2.5 m	91.0%	4.0%	5.0%
3.0 m	92.0%	4.0%	4.0%

Table 12. Tensiometer Data Averages of Plots 1 and 2

	PLOT 1 (kPa)						PLOT 2 (kPa)					
	Depth (meters)						Depth (meters)					
DATE	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
03-Nov	-9.2	-13.4	-17.1	-13.6	-14.9	-12.8	-10.3	-10.0	-11.0	-11.8	-11.8	-10.0
06-Nov	-9.6	-22.1	-24.2	-21.7	-20.8	-11.9	-11.8	-10.0	-12.9	-11.5	-20.9	-10.4
09-Nov	-7.8	-28.1	-29.9	-27.9	-26.1	-14.8	-10.9	-10.3	-14.2	-12.3	-28.0	-10.5
10-Nov	-8.2	-16.2	-19.8	-20.9	-18.9	-16.1	-11.1	-8.8	-11.4	-13.5	-20.9	-10.4
20-Nov	-6.9	-22.9	-27.3	-31.4	-32.4	-23.2	-8.7	-7.8	-12.2	-20.1	-41.0	-10.9
30-Nov	-6.5	-17.4	-17.7	-13.2	-38.9	-27.7	-6.1	-4.9	-12.5	-23.6	-48.6	-11.3
06-Dec	-7.4	-6.8	-14.8	-8.3	-26.6	-26.8	-6.9	-6.2	-6.8	-2.9	-48.4	-11.2
12-Dec	-6.7	-6.9	-18.7	-4.5	-27.2	-27.9	-7.4	-6.1	-6.1	-1.0	-6.0	-8.4
19-Dec	-8.4	-7.2	-19.8	-5.7	-5.9	-6.5	-7.8	-6.0	-6.4	-1.8	-6.4	-5.8
30-Dec	-7.0	-8.3	-9.0	-5.3	-6.7	-5.6	-14.6	-9.9	-7.8	-2.5	-6.7	-7.2
08-Jan	-9.1	-8.6	-8.1	-7.0	-7.2	-6.3	-8.6	-7.4	-8.2	-2.8	-7.7	-6.9
18-Jan	-7.5	-6.9	-7.4	-7.0	-7.5	-6.9	-7.8	-6.2	-7.9	-3.3	-8.1	-7.3
25-Jan	-7.6	-6.7	-6.9	-6.0	-6.6	-6.4	-7.6	-4.9	-6.7	-2.5	-7.4	-7.0
01-Feb	-7.5	-6.2	-6.7	-6.2	-6.1	-5.9	-6.7	-6.4	-6.7	-6.4	-7.2	-6.3
07-Feb	-7.1	-6.2	-6.1	-6.0	-5.9	-4.9	-6.7	-4.0	-6.3	-5.9	-6.3	-5.9
16-Feb	-7.0	-6.6	-6.5	-6.1	-6.1	-5.6	-7.0	-6.3	-6.6	-6.2	-6.5	-6.4
22-Feb	-7.3	-6.5	-6.3	-6.4	-6.2	-5.8	-7.2	-6.5	-6.5	-6.4	-6.5	-6.3
01-Mar	-7.4	-6.8	-6.3	-6.2	-6.0	-5.7	-7.3	-6.9	-6.7	-6.4	-6.5	-6.5
08-Mar	-6.9	-7.2	-6.5	-6.0	-6.0	-5.7	-7.7	-7.2	-6.7	-6.2	-6.4	-6.4
15-Mar	-8.3	-7.0	-6.6	-6.4	-6.2	-5.9	-8.2	-6.9	-6.9	-6.5	-6.6	-6.6
22-Mar	-7.3	-7.1	-6.4	-5.9	-5.8	-5.6	-7.4	-6.7	-6.5	-6.1	-6.1	-6.1
01-Apr	-7.7	-7.4	-6.9	-6.5	-6.2	-5.9	-7.3	-6.9	-7.2	-6.6	-6.7	-6.7
05-Apr	-7.3	-7.1	-6.8	-6.2	-5.9	-5.8	-7.0	-6.4	-6.5	-6.2	-6.0	-6.0
11-Apr	-7.9	-7.3	-6.8	-6.4	-6.0	-5.8	-7.2	-6.8	-6.8	-6.3	-6.3	-6.3
22-Apr	-7.2	-7.5	-6.8	-6.0	-6.1	-5.7	-7.3	-7.2	-6.9	-6.3	-6.4	-6.2
29-Apr	-7.3	-7.1	-6.7	-6.2	-6.1	-5.6	-7.2	-6.7	-6.7	-6.3	-6.2	-6.1
06-May	-7.1	-7.0	-6.8	-5.9	-6.2	-5.4	-6.8	-6.7	-6.4	-5.9	-6.1	-5.7
13-May	-7.4	-6.6	-6.7	-6.1	-6.1	-5.0	-7.0	-6.5	-6.7	-6.2	-6.4	-6.3
20-May	-7.1	-6.8	-6.9	-6.0	-6.2	-5.5	-6.9	-6.9	-6.8	-6.2	-6.4	-6.3
27-May	-6.0	-7.3	-7.0	-6.2	-6.3	-5.6	-7.4	-7.3	-6.9	-6.3	-6.6	-6.6
03-Jun	-6.5	-7.0	-6.8	-5.5	-6.2	-3.8	-6.4	-6.7	-6.7	-6.2	-6.2	-6.0
10-Jun	-6.9	-7.1	-6.9	-5.4	-6.3	-4.0	-7.2	-7.0	-6.9	-6.5	-6.3	-6.4
17-Jun	-7.7	-7.5	-7.1	-5.4	-6.4	-4.1	-7.2	-7.4	-7.2	-6.3	-6.7	-6.6
24-Jun	-7.2	-7.6	-7.3	-5.0	-6.6	-4.0	-7.2	-7.4	-7.5	-6.7	-7.1	-6.9
01-Jul	-8.6	-7.8	-7.5	-5.9	-6.6	-5.3	-8.1	-7.7	-7.7	-6.8	-7.3	-6.8

Table 13. Tensiometer Data Averages of Plots 3 and 4

	PLOT 3 (kPa) Depth (meters)						PLOT 4 (kPa) Depth (meters)					
DATE	0.5	1.0	1.5	2.0	2.5	3.0	0.5	1.0	1.5	2.0	2.5	3.0
03-Nov	-12.5	-11.0	-11.2	-12.3	-11.2	-12.0	-12.0	-10.7	-9.6	-9.5	-26.2	-16.7
06-Nov	-13.4	-10.9	-14.1	-20.0	-17.3	-15.5	-13.0	-10.5	-9.4	-9.4	-26.4	-20.3
09-Nov	-8.0	-11.3	-16.6	-24.1	-23.1	-19.0	-10.2	-10.7	-9.7	-9.6	-26.9	-15.1
10-Nov	-6.7	-11.3	-12.8	-16.5	-16.5	-19.4	-11.2	-10.6	-9.6	-9.5	-27.8	-16.0
20-Nov	-5.7	-10.9	-15.3	-21.2	-31.4	-36.8	-9.7	-8.4	-9.7	-9.6	-33.8	-15.2
30-Nov	-4.7	-6.3	-10.9	-15.9	-35.4	-48.1	-8.0	-5.1	-8.6	-9.2	-30.0	-17.2
06-Dec	-6.3	-6.3	-5.9	-9.8	-31.8	-49.4	-7.6	-6.2	-5.8	-6.1	-5.8	-16.5
12-Dec	-7.2	-6.5	-5.5	-4.8	-10.4	-52.9	-6.7	-6.1	-5.5	-5.4	-1.3	-2.9
19-Dec	-7.2	-6.7	-5.7	-6.0	-6.2	-54.3	-7.5	-6.8	-5.6	-5.7	-2.8	-0.8
30-Dec	-13.8	-8.9	-6.5	-6.5	-7.1	-6.4	-16.6	-8.5	-5.8	-6.4	-2.5	-0.5
08-Jan	-7.9	-8.3	-7.3	-7.7	-7.7	-6.9	-8.9	-8.0	-6.8	-7.0	-2.7	-0.6
18-Jan	-7.7	-8.4	-7.5	-7.4	-8.0	-7.0	-7.7	-7.7	-7.3	-7.4	-2.0	-0.5
25-Jan	-7.2	-7.9	-7.2	-7.7	-8.1	-7.0	-7.8	-7.0	-6.9	-7.4	-2.5	-0.2
01-Feb	-6.7	-7.5	-7.5	-7.6	-8.2	-7.0	-7.8	-7.2	-7.1	-7.4	-6.1	-5.7
07-Feb	-6.8	-7.3	-7.1	-7.2	-8.3	-7.0	-7.9	-7.1	-6.9	-7.4	-7.6	-5.6
16-Feb	-6.8	-7.8	-7.2	-7.6	-8.4	-7.0	-7.9	-7.1	-6.8	-7.5	-7.8	-5.7
22-Feb	-7.2	-7.7	-7.1	-7.7	-8.5	-7.3	-7.7	-6.9	-6.6	-7.4	-7.9	-5.6
01-Mar	-6.9	-7.9	-7.4	-7.3	-8.4	-7.4	-7.8	-7.2	-7.0	-7.4	-7.7	-5.7
08-Mar	-7.3	-8.1	-7.3	-7.7	-8.3	-7.4	-8.0	-7.4	-6.7	-7.4	-7.7	-5.8
15-Mar	-9.2	-8.5	-7.6	-9.2	-8.4	-7.5	-8.5	-7.4	-7.0	-7.3	-7.7	-6.1
22-Mar	-7.1	-7.7	-7.8	-7.2	-7.8	-6.9	-7.8	-7.2	-7.1	-7.4	-7.4	-5.3
01-Apr	-9.2	-8.5	-8.2	-8.7	-8.5	-7.4	-9.0	-7.7	-7.6	-7.6	-7.8	-6.2
05-Apr	-6.7	-7.1	-7.7	-6.2	-7.4	-5.9	-7.0	-7.2	-7.3	-7.2	-6.8	-4.9
11-Apr	-7.4	-8.0	-8.1	-7.2	-7.9	-6.8	-8.6	-7.6	-7.5	-7.5	-7.3	-5.6
22-Apr	-6.4	-7.8	-7.9	-6.5	-7.7	-6.5	-7.5	-7.4	-7.1	-7.2	-7.0	-4.9
29-Apr	-6.8	-7.9	-8.0	-6.8	-7.7	-6.6	-7.8	-7.4	-7.5	-7.4	-7.2	-5.3
06-May	-5.9	-7.5	-8.1	-6.1	-7.6	-6.7	-7.4	-7.5	-7.8	-7.5	-7.3	-5.2
13-May	-7.8	-7.9	-8.1	-7.7	-7.8	-6.4	-8.7	-7.7	-7.6	-7.5	-7.5	-5.8
20-May	-6.7	-7.9	-8.3	-7.6	-7.8	-6.5	-7.9	-7.7	-7.6	-7.6	-7.2	-5.1
27-May	-6.8	-8.2	-8.3	-8.0	-7.9	-6.4	-7.9	-7.9	-7.7	-7.5	-7.3	-5.4
03-Jun	-6.1	-7.7	-8.1	-7.6	-7.6	-6.5	-7.5	-7.7	-7.7	-7.5	-7.1	-5.1
10-Jun	-6.9	-8.0	-8.2	-8.1	-7.9	-6.7	-7.7	-7.7	-7.8	-7.4	-7.1	-5.1
17-Jun	-7.9	-8.4	-8.5	-8.2	-8.0	-6.8	-8.2	-7.8	-7.8	-7.4	-7.2	-5.3
24-Jun	-7.3	-8.2	-8.4	-8.0	-7.8	-6.7	-8.0	-7.9	-7.9	-7.4	-7.2	-5.3
01-Jul	-10.6	-8.8	-8.8	-8.4	-8.3	-7.0	-9.3	-8.4	-8.2	-7.8	-7.6	-6.2

Table 14. Tensiometer Data Averages of Plot 5

PLOT 5

(kPa)

DATE	Depth (meters) 0.5	1.0	1.5	2.0	2.5	3.0
03-Nov	-12.1	-10.9	-10.8	-9.3	-20.2	-11.0
06-Nov	-12.2	-10.9	-12.9	-9.3	-25.8	-16.3
09-Nov	-10.2	-11.0	-10.9	-9.2	-29.9	-21.3
10-Nov	-7.7	-9.8	-9.1	-9.2	-25.1	-17.0
20-Nov	-6.3	-10.0	-10.6	-9.3	-33.3	-27.5
30-Nov	-4.1	-9.2	-10.5	-8.1	-35.0	-34.6
06-Dec	-6.5	-8.6	-6.1	-6.4	-31.3	-34.2
12-Dec	-6.3	-7.4	-5.0	-5.7	-12.0	-23.6
19-Dec	-7.0	-7.8	-5.4	-6.1	-8.1	-6.0
30-Dec	-7.3	-7.6	-5.0	-6.6	-5.4	-6.0
08-Jan	-7.5	-5.2	-4.4	-7.5	-5.3	-6.6
18-Jan	-7.0	-7.1	-2.8	-6.5	-3.1	-5.7
25-Jan	-7.6	-7.7	-2.9	-7.4	-6.8	-6.0
01-Feb	-8.1	-7.8	-8.1	-7.8	-7.0	-6.7
07-Feb	-8.0	-8.3	-7.8	-7.4	-6.9	-6.6
16-Feb	-8.6	-8.5	-8.4	-8.1	-7.3	-6.9
22-Feb	-8.7	-8.9	-8.8	-8.3	-7.5	-7.1
01-Mar	-9.0	-8.9	-8.9	-8.6	-7.6	-7.4
08-Mar	-9.3	-9.1	-9.0	-8.8	-7.8	-7.6
15-Mar	-10.0	-9.1	-9.2	-8.8	-7.9	-7.8
22-Mar	-9.3	-9.3	-9.4	-8.9	-8.0	-7.8
01-Apr	-10.6	-9.7	-9.6	-9.3	-8.3	-8.1
05-Apr	-8.9	-9.3	-9.0	-8.5	-7.8	-7.2
11-Apr	-10.0	-9.7	-9.5	-9.1	-8.3	-8.1
22-Apr	-9.0	-9.3	-9.3	-8.8	-8.1	-7.7
29-Apr	-9.7	-9.7	-9.6	-9.1	-8.3	-7.9
06-May	-9.4	-9.4	-9.5	-9.0	-8.0	-7.7
13-May	-10.7	-9.9	-9.8	-9.4	-8.4	-8.2
20-May	-10.0	-10.0	-10.1	-8.8	-8.8	-8.3
27-May	-9.6	-10.0	-9.9	-6.6	-8.5	-8.1
03-Jun	-9.6	-9.8	-9.6	-8.9	-8.3	-7.9
10-Jun	-9.7	-9.7	-9.9	-8.9	-8.5	-8.1
17-Jun	-10.5	-10.0	-9.9	-9.4	-8.5	-8.2
24-Jun	-10.3	-9.9	-9.7	-9.3	-8.5	-8.0
01-Jul	-12.3	-10.2	-10.0	-9.7	-8.6	-8.4